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FORTRAN IV PROGRAMMING
FOR
CARTOGRAPHY AND TYPOGRAPHY

By

A. V. HERSHEY

Science and Mathematics Research Group

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FOREWORD

The work of this report represents an advance in the application of computers. Programming and computation were charged to the Independent Research Program of the Naval Weapons Laboratory, Project No. RDTE-WR-O-0302/107-1/R0110101. Map and character displays on the CalComp 718 plotter and on the S-D 4060 printer were programmed by Mr. W. H. Langdon. A system of subroutines for the IBM 360 computer was programmed by Mr. R. Gnoffo. Some suggestions about reference material for ancient systems of writing were received from Mr. H. J. Sanborn and from Dr. L. Marwick of the Library of Congress, and a few reports were obtained from the Library Research Service of the Encyclopaedia Britannica. The manuscript was completed by 15 Sept 1969.

Approved for release:

RALPH A. NIEMANN, Head
Warfare Analysis Department

ABSTRACT

Documentation is provided for a new system of cartography and typography. Input to the system is on IBM punched cards. Typographic input is in the FORTRAN IV character set. A card of textual data is followed by any number of cards of functional data. Mnemonic control codes are provided for the functional data. Samples of output from the new system have been prepared on a mechanical plotter and on a cathode ray printer. The limitation to FORTRAN IV is a handicap which should be overcome by the use of an electronic tablet.

INTRODUCTION

The graphic output from an electronic computer is obtained from an automatic mechanical plotter or from a cathode ray printer. The basic component of a mechanical plotter is a pen whose motion in Cartesian coordinates is controlled by incremental motors. The basic component of a cathode ray printer is a modulated electron beam, which is deflected electrically and is focussed magnetically on a fluorescent screen. The action on the screen is recorded on film by an optical camera. In the mechanical plotter the pen is stepped along a straight line between two points in a raster, while in the cathode ray printer the electron beam is made to execute a stroke between two points in a raster. In the Charactron system, the electron beam is deflected to pass through a selected aperture in a character matrix where the electron beam is shaped to the configuration of a character. The repertory of standard characters in the character matrix is very limited. Any character which can be synthesized from a sequence of strokes is a character which can be plotted on the cathode ray printer. The repertory of synthetic characters is unlimited. In the Linotron system, the electron beam is made to scan over the character in parallel lines. The electron beam is modulated to be off over the white area and is modulated to be on over the black area. The modulation of the electron beam is derived from a flying spot scanner. Thus characters may be classified as shaped, stroked, or scanned according to their method of preparation.

Previous reports¹⁻⁴ from the Naval Weapons Laboratory have given documentations of cartographic and calligraphic repertories for electronic digital computers. The cartographic repertories contain data for the coast lines and boundaries of the World, the United States, and the Potomac River. The calligraphic repertories include alphabets of occidental origin and a considerable number of characters of oriental origin. In the occidental repertory there are cursive (Script and Italic) and gothic (English, Lombardic, and German) as well as the standard (Greek and Roman) alphabets. The repertories include many characters of duplex structure, wherein variable line width is achieved by a plotting of lines side by side. The preparation of each repertory was accomplished in two stages. In the first stage, each configuration was approximated by polygonal lines which were sketched on tracing paper or on graph paper. In the second stage, the coordinates of the corners in the polygonal lines were scaled and were recorded in digital form on coding paper. The digitizations are available in the form of punched cards and magnetic tape. Inasmuch as the digitizations were limited to a discrete raster, no map or alphabet could quite be used as an exact basis for the design of the digitizations. The repertories have been enlarged and overhauled to improve their graphic arts quality.

The objective of the present report is the preparation and documentation of a unified system of programming which utilizes these repertories of data. The new system is intended to provide a do-it-yourself capability to programmers in computing centers and is not necessarily intended to replace computer programming for production printing. The primary function of the new system is the preparation of mathematical texts, but secondary functions include the preparation of meteorological, astronomical, electronic, and chemical material. A primary requirement therefore is an unlimited versatility without too much sacrifice in efficiency or quality.

A basic concept of the new system is the organization of a composition into patterns which can be translated or rotated as entities. Superpositions of characters to form such combinations as \tilde{x} , \tilde{A} , or \tilde{X} are popular with mathematicians. They are anathema to the conventional mechanical printers⁵⁻¹⁰, but are no bother for automatic digital plotters. Other patterns are components of electronic circuits, groups in chemical structures, and fractions in mathematical expressions.

In the design of patterns, constant attention must be given to the relationship between the abstract raster in subjective space where design occurs and the actual raster in objective space where display occurs. An important aspect of design is the line width. The possible scalings of a complex character are limited to those discrete values for which the available line widths are in correct proportion to the possible sizes of character. Control of line width in the case of a cathode ray printer depends upon a variation of intensity across the line. Even when the line is generated by the sweep of a circle of uniform intensity, there is a variation of intensity across a long line from zero at the outer edge to a maximum at the center line. The intensity at a particular distance from the center line is proportional to the duration of exposure or to the chord of the circle at that distance.

The digitizations of data are designed for line widths of one raster unit at half intensity in the abstract raster. The line widths at half intensity are two or more raster units in the actual raster.

All input is on punched cards, which can be edited at any time. Three kinds of input consist of map data for cartographic applications, character data for calligraphic applications, and control data for typographic applications. The map data give the geographic coordinates of corner points in polygonal lines which delineate the coast lines or boundaries of the world. Any mapping transformations can be applied to the geographic coordinates to convert them into map coordinates. The character data give the abstract coordinates of corner points in polygonal lines which delineate each character in subjective space. Any affine transformation can be applied to the abstract coordinates to convert them into actual coordinates in objective space. Interspersed among the control cards are textual cards which specify what material is to be printed. Following each textual card can be any number of functional cards which specify how the material is to be interpreted. The instructions for printing are contained in a repertory of mnemonic control codes.

The principal programs in the new system are a cartographic subroutine and a typographic subroutine which are available to any computer insofar as they are written in FORTRAN IV. They make calls to subroutines which provide the interface between the STRETCH computer and the input-output tape mechanisms. The I-O subroutines are written in STRAP language in order to maximize their efficiency of operation. Versions of the I-O subroutines are available for the CalComp 718 mechanical plotter, the S-C 4020 cathode ray printer, and the S-D 4060 cathode ray printer. Brief descriptions of the subroutines are given in Appendix A.

Automatic features of the cartographic routine include cut out zones and line formats. Automatic features of the typographic routine include capitalization, ligaturization, justification, and pagination, but not hyphenation. Flexible provisions of the typographic routine include the alignment of expressions and the ruling of lines and vectors.

A set of samples has been prepared with the objective of demonstrating the versatility of the system. They are presented in Appendices B through G. A complete documentation of all reference material for the samples would be impracticable. A few general references¹¹⁻¹⁸ are given in the Bibliography.

MAPPING SYSTEMS

Research on data digitization and on data retrieval is actively in progress at a number of agencies. Techniques are under study in the United States at the Engineer Topographic Laboratory, Coast and Geodetic Survey, Naval Oceanographic Office, Rome Air Development Center, Aeronautical Chart and Information Center, Army Map Service, and Central Intelligence Agency. Research in Canada is at the Canadian Hydrographic Service. Special data banks of limited application have been prepared at Rome Air Development Center, Aeronautical Chart and Information Center, and Army Map Service. The one major effort toward the digitization of general map data is underway at the Central Intelligence Agency. Completed to date is a data bank with 59000 data for the coast lines of the world and a data bank with 25000 data for the boundaries between nations. The digitizations at the Central Intelligence Agency will continue until the data banks contain many times this number of data.

Most of the known systems for cartography appear to be similar to the pioneering system* for the Naval Ordnance Research Calculator insofar as they take digital data for points on coast lines from an input magnetic tape and reproduce the coast lines in the form of plot instructions on an output magnetic tape. The input tape has been reformatted by various agencies to achieve greater efficiency.

At the Naval Weapons Laboratory there is a cartographic routine which is written in FORTRAN IV and STRAP for the IBM 7030 computer. It utilizes reformatted input data on an IBM 729 Model IV tape drive and prepares systems output for the S-D 4060 cathode ray printer. The time to prepare a Mercator map of the World is 40 seconds. For further information, enquiry may be addressed to Arthur Herring, Naval Weapons Laboratory, Dahlgren, Va. 22448.

At General Dynamics/Convair, a number of programs depend upon a cartographic routine which is written in FORTRAN IV for the IBM 7094 computer. It utilizes reformatted input data and displays output on the S-C 4020 cathode ray printer. For further information, enquiry may be addressed to Walter A. Marggraf, Systems Technology 591-0, General Dynamics/Convair Division, San Diego, California, 92112.

At the University of Michigan, a number of programs depend upon a cartographic routine which is written in MAD for an IBM 7090 computer. It utilizes reformatted input data and prepares output instructions for a 30-inch CalComp plotter. For a Mercator map of the World, the approximate times are two minutes for computing and ten minutes for plotting. For further information, enquiry may be addressed to Waldo R. Tobler, Department of Geography, the University of Michigan, Ann Arbor, Michigan 48104.

At the University of Victoria there is a cartographic routine which is written in FORTRAN IV for an IBM 7040-7094 DCS computer. It utilizes card input and prepares output instructions for a CalComp 563 inkline plotter. For further information, enquiry may be addressed to Keith Newsom, Department of Geography, University of Victoria, Victoria, British Columbia.

At the National Center for Atmospheric Research there are several cartographic routines in FORTRAN IV for the CDC 6600 computer, which has a CDC DD80 microfilm recorder as an on-line output device. Typical time to generate a Mercator projection is a second. For further information, enquiry may be addressed to David Robertson.

*It should be noted that Reference 2 contains typographic errors as follows: in Equation (5), ϕ should be θ , on page 8, line 27, (24) should be (23); on page 9, line 28, (38) should be (39).

Computing Facility, National Center for Atmospheric Research, P. O. Box 1470, Boulder, Colorado 80302

At the Central Intelligence Agency, there is a cartographic system which is called the Automap System¹⁹. The plot program is written in FORTRAN IV, Level H for the IBM 360 series of computers, and may be modified for the IBM 7090 or IBM 7094 computers. Output may be either on a mechanical plotter or on a cathode ray printer. For 59000 data, the running time is approximately 4 minutes on an IBM 360 Model 65 computer. For further information, enquiry may be addressed to Warren E. Schmidt, Cartography Division, Central Intelligence Agency, Washington, D.C. 20505.

PRINTING SYSTEMS

There are many systems for printing material through a computer. Advanced occidental systems are located at Alphametrics, Incorporated and at the Government Printing Office. Advanced oriental systems are located at the Radio Corporation of America and at the Japan Information Center of Science and Technology.

These systems have only limited capabilities with regard to the printing of mathematical work. They do not have the large range of symbols which are required. Insofar as they are line-at-a-time printing systems, the preparation of built up fractions would require a sorting operation in order that the symbols in the fractions would appear in the proper sequence to be printed serially.

Some experiments in computer typesetting have been described by Barnett²⁰, but only with a limited consideration of mathematical work. A printing system for a cathode ray printer has been developed by Goodman²¹, but the repertory was limited to the matrix character set of the cathode ray printer.

A system of input for computer typesetting is under development by Meissner²². The input is on punched cards where a pair of columns is devoted to each character. One column contains textual data while the other column contains functional data. Key punching is coded by a special keyboard which provides subscripts and superscripts in addition to the normal size of Roman and Greek alphabets. For further information, enquiry may be addressed to Loren P. Meissner, Math and Computing Group, Lawrence Radiation Laboratory, Berkeley, California 94720.

A complete program in FORTRAN IV for the printing of music has been prepared by Gabura²³. Input to the program is on IBM punched cards. Initial cards give the key and the time signatures, the title and the composer. For each note, three columns are devoted to the accidental, the name, and the octave, while two columns are devoted to the duration. Each measure is punched on a separate card with continuation cards if necessary. The replacement of flags by beams is under the control of additional cards. For further information, enquiry may be addressed to A. James Gabura, Department of Computer Science, University of Toronto, Toronto, Canada.

INPUT

The central problem of computer typography is the conversion of a manuscript to a form which can be fed into a computer. The ultimate solution would be an electronic character reader. Otherwise it is useful to take advantage of the speed and skill of typists and key punchers, and to utilize the knowledge and experience of an editor.

Machines are available for recording data directly on cards or tape, but the editing and correcting of the data present a problem. It is relatively easy to find a point of correction in a deck of cards, and individual cards can be corrected without disturbance to the rest of the deck. Special equipment is required to locate a point of correction on a tape. The tape must be reproduced up to the point of correction, and must be

reproduced beyond the point of correction. Punched cards are more handy for a do-it-yourself operation.

The many models of IBM keypunch machine give a profusion of printed characters on the punched card. Comparison of the many sets of characters and elimination of conflicts between sets leads to a set of 64 basic characters which contain the 48 basic characters of FORTRAN, a full set of punctuation signs, and a full set of logical symbols for FORTRAN. This 64-character set is illustrated in Appendix B. The keypunch operators have been trained to punch the 48 basic characters of FORTRAN on any of the keypunch machines, but any extension of the character set beyond this minimum standard might require double punching. It is concluded that a strict adherence to the FORTRAN character set would be prudent for the present.

In most systems of typography by computer the textual data and the functional data are intermixed in a continuous string of control data. This makes it difficult to proof read the text or to modify the controls. In the present system of typography by computer a line of textual data is given in a textual card, and the functional data for the line are given in subsequent functional cards. The textual data and the functional data are linked together through the column numbers which are printed on every IBM punched card. Each word of textual data is set off by blanks. Indentation is indicated by leading blanks. Otherwise the first word on each card begins in column 1. The last word on each card may end anywhere short of column 80. All remaining blanks on the card are treated as a single blank by the typographic routine. The design of functional data follows the FORTRAN conventions insofar as blanks are ignored and each field of alphabetical data is separated from each field of numerical data by single punctuation. Functional data are confined to columns 7 through 72 of the punched card. The control data must be ordered systematically because the cards are processed from left to right.

MODES OF OPERATION

Control Codes

The control cards for the typographic routine include modal cards which specify the mode of operation. The typographic routine has four modes of operation. A change of mode occurs whenever the modal card contains one of the words PLOT, PRINT, FRAME, RETURN. Sensing of the mode is applied to the first two letters of each word, and the remainder of the card is available for annotation.

Plot

In the PLOT mode, characters and vectors are plotted under the control of functional cards. Each functional code consists of a two-letter field and one or more numerical fields. A blank numerical field is interpreted as a nonoperation code. The data on a functional card need not be terminated by punctuation, in which case the next card is assumed to be a continuation card. When a period or an asterisk is encountered, the processing of the current functional card is terminated. If a period is encountered, the PLOT mode is continued to the next functional card. If an asterisk is encountered, the next control card is assumed to be a modal card.

Print

In the PRINT mode, characters are plotted or vectors are ruled under the control of textual and functional cards. The functional codes contain two-letter fields and numerical fields as appropriate. No numerical field may be blank, but may contain a sign and any number of decimal digits. The data on a functional card need not be

terminated by punctuation, in which case the next card is assumed to be a continuation card. When a period or an asterisk is encountered, the processing of the current textual card is terminated. If a period is encountered, the PRINT mode is continued to the next textual card. If an asterisk is encountered, the next control card is assumed to be a modal card.

Frame and Return

The FRAME mode terminates a page and advances the film by one frame. The RETURN mode initiates a return of control to the main program.

POSITION AND ORIENTATION

Origin of Coordinates

The digitization of each pattern is referred to an origin of coordinates in the pattern. The typographic routine places the pattern in such a position that the origin of coordinates in the pattern coincides with an origin of coordinates in the abstract raster. A change of the origin is provided by the mnemonic control code OC which is followed by the abstract raster values for the X and Y coordinates of the new origin.

Matrix of Scaling

Orientation and scaling of a pattern are controlled by a general matrix which is applied to each vector before it is plotted. A change of the matrix is provided by the mnemonic control code MS which is followed respectively by the numerical values of the four components of the matrix in the conventional order of arrangement.

Registration

The typographic routine maintains continuously an X-register and a Y-register, which contain the coordinates of a current point in the abstract raster. In the PLOT mode, the X, Y registers point to the centroid of a plotted character or to the origin of a plotted vector. The values of the coordinates are reset to new values by the mnemonic control code XY, which is followed by the new values for X and Y in a pair of numerical fields. In the PRINT mode, the X, Y registers point to the edge of a plotted character. The values of the coordinates are reset to new values by the mnemonic control codes X or Y, or are incremented to new values by the mnemonic control codes H or V. The possible two-letter codes are XY, HY, XV, HV for all of the combinations of resets or increments. Each code is followed by two numerical fields which give the resets or increments in abstract raster units.

Alignment

A pair of column numbers which are separated by a comma defines a span of distance in the abstract raster. The span extends from the left edge of the character in the first column to the right edge of the character in the second column. If only one column number is listed, the span is understood to coincide with the width of the one character in that column. A horizontal displacement of characters occurs when the functional code is a quading code. The argument of a quading code consists of two parts. The first part defines the span of characters which are displaced by quading. The second part defines a span of characters if the two parts are separated by a solidus, while the second part defines a coordinate in the abstract raster if the two parts are separated by a dollar sign. The second part defines the position to which the first part is displaced by quading.

Alignment of a whole line with the first part of the argument centered over the

second part of the argument occurs if the mnemonic control code is QA. The left edge of the first part is aligned flush with the right edge of the second part if the mnemonic control code is QL. The right edge of the first part is aligned flush with the left edge of the second part if the mnemonic control code is QR. The first part is centered over the second part if the mnemonic control code is QC.

Quanta

If a number in a numerical field is followed by Q, the number is multiplied by a quantum. In the PLOT mode, the quantum is 10^{-4} for the scaling matrix. In the PRINT mode, the quantum is 4 for horizontal increments and is 12 for vertical increments.

CHARACTER SPECIFICATION

Shaped Characters

The meta codes for character orientation, character size, or character case are forwarded to the S-D 4060 cathode ray printer when they are preceded respectively by the mnemonic control codes OK, SK, or CK.

In the PLOT mode, a character number which is preceded by O is interpreted as the octal number of a shaped character. The octal numbers for the CalComp plotter or for the S-C 4020 cathode ray printer are those in the programming manuals, while the octal numbers for the S-D 4060 cathode ray printer are those of the EBCDIC character set. The plotting of a character is initiated by the mnemonic control code PC, which is followed by the number of the character to be plotted.

Stroked Characters

The meta code for line width is forwarded to the S-D 4060 cathode ray printer when it is preceded by the mnemonic control code WL. A composite line with six times the width of a single line is generated if the meta code is 6. The composite line terminates at octagons around the ends of the single line.

In the PLOT mode, a character number which is purely numerical is interpreted as belonging to a character from the stroked character set. The plotting of the character is initiated by the mnemonic control code PC, which is followed by the number of the character to be plotted.

In the PRINT mode, the character number is derived from the alphanumeric codes in the textual data, as interpreted in accordance with the mnemonic codes in the functional data.

Inasmuch as only 48 FORTRAN characters are used to evoke 1094 letters and signs, each FORTRAN character has many meanings. The present status of the meanings of the FORTRAN characters is indicated by the transliterations in Appendix C. The meaning which is in effect at any instant is controlled by the settings of various control indices. All control indices remain set until they are changed by a new control code.

All of the alphabets in the occidental repertory have both lower case and upper case with the exception of the cartographic alphabets which are too small to have legible lower cases. The difference in character number between lower case and upper case is 100 units throughout, and capitalization is under the control of a universal index which has either of the values 0 or 100. The case is changed to lower case or to upper case by the mnemonic control codes LC or UC.

There are two complete sets of letters, numerals, and signs in the complex style of character. One set is indexical in size while the other set is normal in size. The difference in character number between the two sets is 1000 units throughout, and the size of character is under the control of a universal index which has either of

the values 1000 or 2000. The size is changed to indexical size or to normal size by the mnemonic control codes PI or PN.

There are fourteen styles of letter in the occidental repertory. The character numbers vary from one style to the next under the control of an index which is reset by two-letter mnemonic control codes. Within any style of letter there may be two or four variants all of which are represented by the same FORTRAN character. A variant is specified to be primary, secondary, tertiary, or quaternary respectively by the mnemonic control codes VP, VS, VT, or VQ.

Roman and Italic

In the Roman and Italic alphabets there are two variants according to whether or not ligatures are used in place of multiple sets of letters. When the presence of a ligature is sensed by the typographic routine, the first letter of the set of letters is replaced by the ligature and the other letters are suppressed.

Greek

In a phonetic transliteration of Greek into FORTRAN each Greek letter is represented by a single Roman letter with four exceptions. The characters θ , ϕ , χ , ψ , are represented by the letter pairs TH, PH, CH, PS. There is no representation in the Greek version for the aspirate H in the Roman version. The letters E and H both are represented by E, while the letters O and Ω both are represented by O. The letter T is represented sometimes by U and sometimes by Y. There are two forms of lower case sigma, one of which is used often at the end of a word. The letter pair $\Pi\epsilon$ may occur in a compound word.

In a mathematical transliteration of Greek into FORTRAN the use of letter pairs in a code of conversion would lead to inefficiency and confusion. A phonetic conversion can be preserved if ϕ , χ are represented by F, C. The remaining letter pairs must be replaced arbitrarily by a selection from the remaining Roman letters. This may be done on a morphological basis. The obvious choices for H, θ would be H, Q and perhaps a good choice for ψ , Ω would be Y, W. This leaves the two cases P, X where Greek characters are not matched with their isomorphic counterparts, but to interchange them would put too much strain on their phonetic equivalence*. For a couple of Greek letters there are variations in style between which a distinction in meaning is made in mathematical work.

Thus there must be four variants in the transliteration of the Greek alphabet into the FORTRAN character set.

Russian

In the transliteration of Russian into FORTRAN there are two Russian characters which indicate palatalization and have no counterparts in the Roman alphabet. They can be represented arbitrarily by an asterisk. Several single Russian characters are represented by two or four Roman letters. There are two variants of E, both of which may appear together in a single word. Either of the Russian characters Π or TC may be represented by the Roman letters TS. It is evident that a dual variance is required for the transliteration of Russian into FORTRAN.

German

In the transliteration of German into FORTRAN the umlaut is expressed by a pair

*This mathematical transliteration is used also by Meissner of the Lawrence Radiation Laboratory.

of asterisks after the character to which the umlaut applies. The typographic routine automatically replaces the asterisks by double dots which are repositioned over the previous character. There are two forms of the lower case German S, one of which is used often at the end of a word. The German ligatures ß and ð are represented by the Roman letters SS and TZ. It is evident that a dual variance is required for the transliteration of German into FORTRAN.

Signs

The FORTRAN character set is inadequate to express mathematical signs, and each FORTRAN sign must have many meanings. Included among the signs are punctuative, parenthetic, conjunctive, predicative, and modificative signs. Among the commonly used punctuative signs are the comma, semicolon, colon, apostrophe, period, interrogation point, exclamation point, and quotation marks. This makes four variants for each of the FORTRAN punctuative signs. Among the parenthetic signs are parentheses, brackets, braces, and elbows in two sizes. This makes a total of eight variants of each parenthetic sign. Even if the two sizes are distinguished by case there still remain four variants for each case.

Character Numbers

Any character may be referenced by its number in the character repertory. Reference by character number overrides any reference by mnemonic code. A zero for a character number is a skip code, while a 10000 for a character number gives a justifiable blank. Several character numbers give blanks of zero width, which are useful for positioning operations.

Blanks

A blank is interpreted as a full space when the control codes are VP, VS, while the blank is interpreted as a half space when the control codes are VT, VQ.

CHARACTER SPACING

Control Codes

In the PLOT mode, the values of X and Y remain constant until they are reset. In the PRINT mode, the value of X is incremented by the sum of character half widths and an intercharacter spacing after each character has been selected. The value of X is reset to the left margin and the value of Y is incremented by the sum of 32 and an interline spacing after each line is completed. The spacings are changed by the mnemonic control code IS, which is followed by two numerical fields with the intercharacter spacing in the first field and with the interline spacing in the second field.

The size of character is changed to indexical size and the level of the line of printing is shifted to the subscript level or to the superscript level by the mnemonic control codes SB or SP. The level of the line of printing is shifted back to the principal level and the size of character is restored to the indexical size or to the normal size by the mnemonic control codes PI or PN.

Em and En

In conventional printing, blocks of type are locked together in a printing form. When an impression is taken, characters are transferred from the faces of the type. Around each printed character is a rectangular area of white space, or character block, which corresponds to the cross section of the body of the type block. The height

of the character block is proportional to the size of the type. The height of the character block is the em of the type, and the size of the em is the measure of the size of type. When no leading is used between lines of type, the em is the distance from the baseline of any line to the baseline of the next line. The en is half the em. The spacing between words in a line of type is normally one en. The unit of measure for the em and the en is the printer's point. There are 72 points in one inch.

The details of design in any style of letter can be measured in printer's units. There are 18 printer's units in one em. The distance from base line to top line of the capital letters varies with the style of letter, but a representative value is 12 units. The width of the character block is normally an integral number of units.

In the standard printing of mathematical texts the values of the em are 6 points, 8 points, and 10 points for the various sizes of indexical and normal characters.

In cathode ray printing, characters are placed with their centroids anywhere in the raster, and adjacent characters can overlap. In a simulation of conventional printing, each character in a word is assigned a character width, which is an integral number of raster units.

In the S-D 4060 system, the heights of the four sizes of shaped character are 24, 32, 40, 48 actual raster units, while the values of the em are 38, 52, 64, 77 actual raster units respectively.

In the present system, the distance from the center line of the bottom serif to the center line of the top serif is 13 abstract raster units for the indexical size of character and is 21 abstract raster units for the normal size of character. The em is 20 abstract raster units for the indexical character set and is 32 abstract raster units for the normal character set.

Horizontal Spacing

The spacing between letters should not be so small that the letters are not individually distinct, yet the spacing should not be so large that the letters in a word fall apart. The correct spacing is determined by the response of the eye and mind. It must be possible for the reader to grasp the significance of a word in a single glance.

In the simplest assignment of spacing, the clearance between the left extremity of a character and the left edge of its character block as well as the clearance between the right extremity of the character and the right edge of its character block are the same for all characters. It has long been known that uniformity of clearance does not give uniformity of appearance except in the boldest styles of lettering. Deviations from uniformity are required in order to compensate for various amounts of concavity between extremities at the sides of characters. Although the letters H and X have the same arrangement of serifs, the clearances for H must be larger than the clearances for X, and the clearances for X in turn must be larger than the clearances for Y or V. That the best clearances for letters are a function of their outer contours and not their inner structure is apparent from the fact that the clearances for the letter H are the same as the clearances for the letter I.

The input data for the computer are just the center lines of relatively broad stripes between positions in a relatively coarse raster. It is difficult to judge the ultimate appearance of a character from a sketch of the center lines alone. It is necessary to prepare a scale drawing of each full character on a slip of cardboard of the correct width. Assemblages of these slips of cardboard can be stuck to the office door and can be viewed at sufficient distance to reduce the image at the retina of the eye to a proper size. Decisions with regard to spacing can be verified from large scale plots on the cathode ray printer.

The spacing between letters was tested at first by a scanning of plots where each letter was sketched between each other letter of the alphabet. Slight errors in spacing were not apparent in such a profusion of letters. The ratio of space perception to sketch preparation is a maximum in such statements as "A quick brown fox jumps over the lazy dog", or "I pack my box with five dozen liquor jugs". These statements do not provide specific cases where the spacings are especially critical. Ultimately a set of words was found such that each letter was imbedded in a matrix of other letters with relatively uniform spacing. Particularly difficult words are NAVAL and TILTING because of the open spacing between A and V or L and T. The spacings for symbols were tested in the expression HHXHH where X is any character. The spacing for the symmetric combination HH was used as the standard of calibration, and the spacing for the symmetric combination OO was adjusted to appear the same. The spacings for other letter pairs were adjusted with the standard letter pairs in close juxtaposition. The clearances for all of the letters were built up in this systematic fashion.

In the standard alphabets which appear in print the absence of contact between adjacent letters is assured by variations in the width of serifs. Although the serifs of I are centered on the stem of I the serifs of V are offset slightly with respect to the diagonals of V. The possible offsets in the present system are limited to relatively drastic amounts by the discrete raster. Offsets would be too severe in the case of the indexical character set and contact between serifs has been allowed to occur in this smaller character set. Offsets are considered to be not too severe in the case of the normal character set and separation between serifs is not less than two raster units in this larger character set.

The uniformity of the alphabets when they are used in the printing of actual words was confirmed by the word lists in Appendix F. The use of all capitals in printing is not proper in the case of the Gothic alphabets, where the capital letters are intended only for use as initial letters. Words with all capitals are included in the lists only to demonstrate uniformity of spacing.

Subscripts and superscripts are used often in conjunction with Italic lettering. Their horizontal position reflects partially the slant of the Italic lettering. Whenever the level of printing advances from the principal level to a superscript level or from a subscript level to the principal level, two abstract raster units of additional spacing are inserted ahead of the next character.

In the previous report³, precise details of the design of each character were presented in the form of large scale plots so that the details would be available for the design of patterns. A useful aid to design is just a listing which gives the number of each character, a name for the character, and the digital coordinates for key points in the character. For cartographic applications the coordinates of the start and stop of the character line are listed while for typographic applications the coordinates of the left and right edges of the character block are listed.

Vertical Spacing

In the standard printing of mathematical texts, one or two points of additional leading are inserted between lines of text, while 2 to 4 points of additional leading are inserted between lines of mathematics.

In the typing of a mathematical text on the Varityper, the horizontal spacing is at 12 characters per inch and the vertical spacing is at 6 lines per inch. Insofar as Elite type are the same size as 10 point type, the standard typewriter spacing of 6 lines per inch corresponds to a 10 point body with 2 points of leading. The spacing between lines of text is 12 points, the spacing between a line of text and a line of mathematics

is 20 points, and the spacing between lines of mathematics is 16 points.

In the present system, the spacing between lines of text is 24 abstract raster units for the indexical size, and is 40 abstract raster units for the normal size.

In conventional printing, subscripts may be placed so that their center lines are even with the lower edges of principal characters, or so that their lower edges are even with the lower tips of parenthetical symbols. Superscripts may be placed so that their upper edges are even with the upper edges of the principal characters, so that their center lines are even with the upper edges of the principal characters, or so that their upper edges are even with the upper tips of parenthetical symbols. In the present system, the center line of the subscript level is lowered 10 abstract raster units below the center line of the principal level while the center line of the superscript level is raised 10 abstract raster units above the center line of the principal level.

LINES AND VECTORS

The meta code for line width is forwarded to the S-D 4060 cathode ray printer when it is preceded by the mnemonic control code WL. A composite line with six times the width of a single line is generated if the meta code is 6. The composite line terminates at octagons around the ends of the single line.

In the PLOT mode, a vector is drawn between two points in the abstract raster. The coordinates of the starting point are obtained from the X, Y registers, while the coordinates of the stopping point are given by the functional data. The plotting of a vector is initiated by the mnemonic control code PV, which is followed by the coordinates of the end point of the vector to be plotted.

In the PRINT mode, a line is ruled through a character or a vector is plotted between characters. A pair of column numbers which are separated by a comma defines the span of a line or vector. The span of a line extends from the left edge of the character in the first column to the right edge of the character in the second column. If only one column number is listed, the span is understood to coincide with the width of the one character in that column. The span of a vector extends from the centroid of the character in the first column to the centroid of the character in the second column.

The ruling of a line is initiated by the mnemonic control code RL, whose argument consists of two parts. The first part is the column number of that character whose centroid coincides with the Y-coordinate of the ruled line, and the second part is the pair of column numbers whose characters determine the span of the X-coordinates of the ruled line. The character which determines the Y-coordinate of the ruled line is suppressed.

The ruling of a vector is initiated by the mnemonic control code RV, whose argument gives the pair of column numbers of the characters at the ends of the ruled vector. The characters at the ends of the ruled vector must be blanks if the ruled vector is to be plotted with plain ends.

CONTROL LINKAGE

Each textual card is read into one buffer and each functional card is read into another buffer. Each character of textual data is replaced by three numbers which consist usually of a character number, the X-coordinate of its centroid, and the Y-coordinate of its centroid. These sets of three numbers are stored in an output buffer. The textual data are processed in strings of characters, all with the same settings of the control indices. The control indices are reset by strings of functional codes, all at the same position in the textual data. Return from the processing of

functional data to the processing of textual data is signalled by a column number between parentheses. The processing of textual data is continued through the column whose number appears between the parentheses.

OUTPUT

Output from the STRETCH computer consists of tapes which contain instructions for the various printer systems. Output from the S-D 4080 cathode ray printer is 35 mm negative film (black on white). The 35 mm negative film is enlarged in an enlarger to give an $8\frac{1}{2}'' \times 10''$ negative film (white on black). After the $8\frac{1}{2}'' \times 10''$ negative has been spliced and opaqued, it is used in a plate maker to prepare the offset plate (black on white). The plate is wetted and is used in an offset duplicator to run off the pages of the final report.

AUTOMATION

Editorial Policy

A problem in the design of a typographic routine is the determination of how much work can be performed by the computer and how much effort must be expended by an editor. The ease with which computer input can be corrected tends to reduce the necessity for prior design and tends to increase the feasibility of posterior intervention.

Editorial intervention is essential for mathematical material where text and equations are intermingled. A page of printing must be justified vertically to prevent any equation from straddling the lower border of the page. The amount of white space with which each equation is surrounded must be adjusted to keep all equations within the borders of the page.

If a line number control is not zero, the typographic routine prints, in shaped characters at the right margin, the vertical coordinate of the lower edge of each line of type, as an aid to editorial analysis.

Capitalization

It is assumed that the author has followed good practice to the extent of starting every sentence with a letter. In the autojustification submode, the first letter of a paragraph is capitalized. The beginning of a subsequent sentence is sensed whenever a period, interrogation point, exclamation point, or quotation mark is followed by a blank, and the first letter of the next sentence is capitalized automatically. In any event, the automatic capitalization can be overridden by a contrary control code. All other capitalizations including the logogram I are under the control of the capitalization index for which the mnemonic codes are LC and UC.

Ligaturization

The typographic routine examines each sequence of letters in the text to determine whether there should be a combination into a ligature. Automatic ligaturization can be overridden by a change of variant with the control codes VP, VS, VQ, VT.

Justification

A line of print is transferred to a buffer one word at a time until the last word straddles the right margin. If the end of the accumulation of words is nearer to the right margin with the last word excluded, then justification is executed without the last word. If the end of the accumulation of words is nearer to the right margin with the last word included, then the length of line is tested to determine whether justification would reduce the interword spaces by more than half. If the interword spaces would

not be reduced too greatly, then justification is executed with the last word included. Automatic justification is turned on or off by the mnemonic control codes AJ or NJ.

Hyphenation

There apparently are no completely automatic rules for hyphenation. Tactics on hyphenation range from no hyphenation at all to the search of a complete dictionary with hyphenation of every word. In the present system, justification is executed without hyphenation. If a trial run indicates a need for hyphenation, the text can be broken at the point of hyphenation with the text before hyphenation in one record and with the text after hyphenation in the next record. At the break in text there is inserted a hyphen and a blank, which will be treated as the end of a word by the typographic routine.

Margination

If a trial run reveals an unsuitable margination, the text can be broken at a new point with part of the text in one record and with part of the text in the next record. A specification for new margination is inserted next after the break in text. Control of margination is provided by the mnemonic code MA which must be followed respectively by the abstract raster values for the left border, the right border, the upper border, and the lower border.

Pagination

Whenever a line of print with its attendant white space would extend below the lower margin, the typographic routine executes automatically a frame advance and begins to print the line of print at the top of the next frame.

Pages can be headed or numbered outside the boundary of a single frame on the S-D 4060 cathode ray printer if the film is advanced with a pulldown of four perforations.

SAMPLES

Prescriptions

The criterion for good composition is uniformity of appearance, for which the ultimate gauge is the eye and mind. Basic guidance to good composition is provided by prescriptions for spacing, although uniformity of appearance may require deviations from the prescriptions.

A number of samples are given in the appendices to illustrate various prescriptions of spacing. The starting point for the samples was a set of drawings of patterns on graph paper. The drawings were digitized to obtain coordinate data. The control data for the samples constitute a repository for the prescriptions of spacing.

The material in the samples was chosen to convey real meaning as well as wide versatility. The preparation of the samples was a certification of the mnemonic control codes for plotting and printing.

Electronics

Electronic diagrams are a grid of connecting lines between component elements. Wherever two lines cross, a dot is placed in the intersection if the lines are connected, while no dot is placed in the intersection if one line jumps across the other line. The size of dot must be correlated accurately with the thickness of line so that the connections are clearly indicated. Measurements indicate that the ratio of diameter of dot to thickness of line ranges from four to six in published examples. A ratio of seven has been adopted for the present system.

The spacing between connectors must be compatible with the sizes of components. Limitations on the size of symbol for vacuum tubes or transistors are imposed by limitations on possible radii of digitized circles. In the present system a basic interval of 100 abstract raster units has been selected for the spacing between connectors.

In published diagrams, transistors are drawn with bases in various positions which range from center to more than a quarter diameter off center. The leads from emitter or collector break inside of envelope, at envelope, or outside of envelope.

A uniform design has been adopted as illustrated in Appendix G.

Chemistry

Chemical formulae in inorganic chemistry are similar in form to mathematical formulae and follow the same prescriptions for spacing.

Structural formulae in organic chemistry are a net of connecting lines between atomic symbols. Two types of connection between symbols are apparent. In one type of connection, the lines would pass through the centers of the symbols if the lines were extended. In the other type of connection, the lines extend from a point at the right of the center of the left symbol to a point at the left of the center of the right symbol. The first method of connection has the advantage that single, double, and triple bonds can be represented with lines of a common length, while the second method has the advantage that the structural formulae can be packed into less space.

A majority of the bonds can be represented by line elements which are included in the character repertory. For certain ring structures the bonds are not included among the characters in the character repertory. Blanks of zero width can be set up as markers at prescribed positions relative to the symbols. The markers are connected ultimately by vectors through reference to the mnemonic code for ruling vectors.

Relatively intricate structural formulae are illustrated in Appendix G.

Mathematics

The basic unit of a mathematical expression is a composite line of characters of indexical size or of normal size at the principal level and with characters of indexical size at a subscript level or at a superscript level. The subscripts or superscripts may themselves be complete lines of characters.

A line of characters at normal size may contain letters, numerals, or signs. Included in the line may be case fractions with numerals of indexical size. The numerals are lowered or raised by 12 raster units or one Q to bring them into position for the denominator or numerator. The repertory of case fractions is unlimited. When letters are used as symbols they are printed in italics. When letters are used in abbreviations, they are printed in Roman. Case fractions and abbreviations are separated from other symbols by small spaces of 4 raster units or one Q.

Included in the line of characters may be conjunctive signs or predicative signs which are separated from other characters in the line by spaces of one half en. In the indexical size, the spaces are equivalent to 6 abstract raster units or to character number 1196, while in the normal size, the spaces are equivalent to 8 abstract raster units or to character number 2198.

The vertical space which is required by a line of characters at indexical size depends upon whether subscripts or superscripts are present. The space requirement is 24 abstract raster units or two Q if no subscripts or superscripts are present. The vertical space which is required by a line of characters at normal size is 48 abstract raster units or four Q regardless of whether subscripts or superscripts are present.

A line of characters at normal size may contain a built-up fraction in which the

denominator and the numerator both are complete lines of characters. The denominator is centered at 24 abstract raster units or 20 below the vinculum and the numerator is centered at 24 abstract raster units or 20 above the vinculum. A built-up fraction in a line of characters is separated from the other characters in the line by spaces of one half en.

Parentheses, integral signs, and radicals are provided at two sizes for both the indexical set and the normal set of characters. The smaller symbols are used in single lines of characters while the larger symbols are used in lines with built-up fractions.

For a line of characters at normal size, the limits of summation or integration are set at a distance of 20 below or above a single line of characters, but the limits of summation or integration are set at a distance of 30 if there are built-up fractions in the line of characters.

The preparation of a mathematical expression is accomplished in three stages. In the first stage, the textual data are converted character by character from the FORTRAN format to the final format in accordance with the functional data. It is convenient at this stage to set up occasional reference frames with zero as origin in order to assemble certain characters in prescribed patterns. The basic units of the mathematical expression have their final arrangement internally, but they do not have their final positions relative to each other. In the second stage, the basic units are shifted under control of the mnemonic codes for quading to bring together the units which belong in contact with each other, or to align units which should be centered with respect to each other. The entire expression is flushed left, flushed right, or centered on the page as the case may be. In the third stage the vincula and the rules are plotted under control of the mnemonic codes for ruling lines or ruling vectors.

Samples of mathematical printing are given in Appendix G

DISCUSSION

The printing of mathematics is difficult because of the large volume of functional data which is required for each mathematical expression. It is necessary to keep in mind the settings for variant, size, style, and case of character along with the settings of the horizontal and vertical registers. The difficulty could be alleviated in various ways. More reliance could be placed on character numbers for special signs while less reliance was placed on the FORTRAN transliteration. Special tallies could be developed on which a running record could be kept of the current status. A better solution would be a large keyboard or electronic tablet where all of the characters are laid out with separate banks for each size, style, and case. This should be coupled with a cathode ray display unit which shows at any instant the status of the preparation. Such equipment is in use already by Kuno^{20,21} at Harvard for the manipulation of Chinese characters.

It was hoped that the new system of cartography and typography would be useful to programmers in any agency where the limitations on equipment are similar to the limitations at the Naval Weapons Laboratory. Although it was necessary to limit input to FORTRAN punched cards, it was possible to obtain output from a CalComp 71B mechanical plotter or from an S-D 4060 cathode ray printer. The mechanical plotter provides accurate line control, whereas the cathode ray printer provides high speed performance. In an effort to minimize degradation of quality in the preparation of the present report, the cathode ray printer was used for check out, but the mechanical plotter was used almost entirely in the preparation of the final version.

CONCLUSION

It is concluded that the present system can be used for the preparation of mathematical material, but the restriction of the input to FORTRAN punched cards is a handicap which should be overcome by the use of an electronic tablet.

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APPENDIX A

PROGRAMMING SUMMARY

SUBROUTINES

IBM 7030

The following general purpose programs are basic to the cartographic subroutines and to the typographic subroutines.

STRETCH SUBROUTINE TO READ ALPHAMERIC RECORD

```
*****
SUBROUTINE RDAMRC (NU, LC)
*****
NU = SYMBOLIC UNIT NUMBER (FORTRAN INTEGER)
LC = ARRAY OF CHARACTER NUMBERS (FORTRAN INTEGERS)
```

An 80-column card record is read from a tape with unit number NU. The contents of the record are converted character by character into the corresponding FORTRAN integers and are available in the array LC.

STRETCH SUBROUTINE TO WRITE ALPHAMERIC RECORD

```
*****
SUBROUTINE WRAMRC (NU, MC)
*****
NU = SYMBOLIC UNIT NUMBER (FORTRAN INTEGER)
MC = ARRAY OF CHARACTER NUMBERS (FORTRAN INTEGERS)
```

The contents of the array MC are converted number by number into the corresponding BCD characters and are written as an 80-column card record on a tape with unit number NU.

STRETCH SUBROUTINE TO READ CHARACTER DIGITIZATION

```
*****
SUBROUTINE RDCHDT (NU, AI, AD)
*****
NU = SYMBOLIC UNIT NUMBER (FORTRAN INTEGER)
AI = INDEX ARRAY (SYMBOLIC ADDRESS)
AD = DATUM ARRAY (SYMBOLIC ADDRESS)
```

The data on an input tape with unit number NU are read into memory. The format of each datum is changed from two BCD digits with nine's complements to seven binary bits with sign bit. For each character there is an entry in the index array AI, and there are digital coordinate data in the datum array AD. The subroutine continues to operate until it senses a NORC end-of-file on the input tape.

STRETCH SUBROUTINE TO EXTRACT CHARACTER BLOCK WIDTH

```
*****
SUBROUTINE XTCHWD (NC, AI, AD, LC)
*****
NC = CHARACTER NUMBER (FORTRAN INTEGER)
AI = INDEX ARRAY (SYMBOLIC ADDRESS)
AD = DATUM ARRAY (SYMBOLIC ADDRESS)
LC = CHARACTER ARRAY (SYMBOLIC ADDRESS)
```

The character width only for the character with index number NC in the index array AI and the datum array AD, is made available as a pair of FORTRAN integers in the array LC.

STRETCH SUBROUTINE TO EXTRACT CHARACTER DIGITIZATION

```
*****
SUBROUTINE XICHDT (NC, AI, AD, LC)
*****
NC = CHARACTER NUMBER (FORTRAN INTEGER)
AI = INDEX ARRAY (SYMBOLIC ADDRESS)
AD = DATUM ARRAY (SYMBOLIC ADDRESS)
LC = CHARACTER ARRAY (SYMBOLIC ADDRESS)
```

The full coordinate data for a character with index number NC, in the index array AI and the datum array AD, are made available as FORTRAN integers in the array LC.

IBM 360

The following general purpose programs provide the linkage between the STRETCH and the CalComp 718.

ASSEMBLY LANGUAGE SYSTEM FOR ALPHAMERIC RECORDS

```
*****
CALL RDAMRC (NU, LC)
An 80-column card record is read from a tape with unit number NU. Each 6-bit
character is converted to the corresponding FORTRAN integer which is stored serially
in the 80-number array LC.
*****
CALL WRAMRC (NU, LC)
The 80-number array LC of FORTRAN integers is converted serially into 6-bit
characters which are written as an 80-column card record on tape with unit number
NU.
*****
CALL FSR (NU, NR)
Space forward NR records on tape unit number NU.
*****
CALL BSR (NU, NR)
Space backward NR records on tape unit number NU.
*****
CALL FSM (NU, NF)
Space forward NF files on tape unit number NU.
*****
CALL BSM (NU, NF)
Space backward NF files on tape unit number NU.
*****
CALL WTM (NU)
Write tape mark on tape unit number NU.
*****
CALL REW (NU)
Write tape mark and rewind tape unit number NU.
*****
```

FORTTRAN SUBROUTINE TO PLOT ON CALCOMP 718

SUBROUTINE PCC718 (NI)

NI = INPUT TAPE NUMBER (FORTRAN INTEGER)

The output tape is opened by external reference to subroutine PLOTS in the CalComp software. Control data in the format of plot functional codes are read from the input tape NI and are converted to CalComp plot instructions on the output tape by internal references to the subroutines SYMBOL and PLOT. The output tape is closed by external reference to subroutine PLOT with a pen control code of 999.

CalComp 718

Inasmuch as the word length for output tape from the IBM 7030 computer is incompatible with the word length for the input tape to the CalComp 718 flatbed, it has been necessary to use the IBM 360 computer as an intermediate stage. This has the advantage that the main program on the IBM 360 can be written in such a way that each successive frame of printed material is displaced out of the way of previous frames on the flatbed.

Instructions for the CalComp plotter are prepared through references to CalComp software in the IBM 360 computer. The scale factor in the CalComp subroutine FACTOR can be reset through a special mnemonic FX on the control tape. The special mnemonic specifies the number of inches per raster unit.

FORTTRAN CARTOGRAPHIC SUBROUTINE (CALCOMP 718)

SUBROUTINE CTGPHC (LW, KF, CF, CA, NI, NO, GNLTRN)

LW = WIDTH OF LINE (FORTRAN INTEGER)
KF = FORMAT ARRAY (SYMBOLIC ADDRESS)
CF = FIELD ARRAY (SYMBOLIC ADDRESS)
CA = AREA ARRAY (SYMBOLIC ADDRESS)
NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
EXTERNAL GNLTRN (AQ, FP)
AQ = ARGUMENT ARRAY (SYMBOLIC ADDRESS)
FP = FUNCTION ARRAY (SYMBOLIC ADDRESS)

Map data are read one card record at a time from an input tape with unit number NI. The geographic coordinates in degrees and minutes are converted to floating point values in degrees. Reference is made to an external subroutine GNLTRN to convert geographic coordinates in array AQ to map coordinates in array FP. Any mapping transformation may be used in subroutine GNLTRN. The floating point values of map coordinates are scaled and masked to restrict the plotted line to the bounds as delimited by array CA for the mapped area and by the array CF for the printer field. The units of FP, CA, CF must be consistent but may be arbitrary otherwise. Plot instructions are generated in accordance with the line width LW and the format KF. The dimensions LW and KF are expressed in raster units. The scaling factor from raster units to inches is fixed at 0.01. Plot instructions in decimal format are written through IOCS on an output tape with unit number NO. The subroutine continues to operate until a NORC end-of-file is sensed on the input tape.

FORTRAN TYPOGRAPHIC SUBROUTINE (CALCOMP 718)

SUBROUTINE TPGPHC (NL, NI, NO, AI, AD)

NL = 0 FOR NO PRINTING OF UNDERLINE LEVELS
NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
AI = INDEX ARRAY (SYMBOLIC ADDRESS)
AD = DATUM ARRAY (SYMBOLIC ADDRESS)

Control data are read one card record at a time from an input tape with unit number NI.

In the PLOT mode, stroked characters from the CalComp set, stroked characters from the index and datum arrays AI and AD, and arbitrary vectors are plotted at any coordinates and with any scaling as specified by the control data.

In the PRINT mode, textual data are plotted and arbitrary vectors are ruled as specified by functional data. Ligaturization, capitalization, and justification of the textual data are executed under control of the functional data. Printing of underline levels for diagnostic purposes is under the control of the parameter NL.

Plot instructions are written in decimal format through IOCS on an output tape with unit number NO. A RETURN is written on the output tape whenever FRAME is sensed on the control tape. Operation is terminated whenever RETURN is sensed on the control tape.

S-C 4010 (simulated on the S-D 4060)

The following programs generate systems output for the CRT printer.

STRETCH SUBROUTINE TO EXTRACT CHARACTER DATA FROM BLOCK 0130

SUBROUTINE XCD130 (NC, IC)

NC = CHARACTER NUMBER (FORTRAN INTEGER)
IC = CHARACTER ARRAY (SYMBOLIC ADDRESS)

The index array and the datum array for a mathematic repertory are packed in a storage area of the subroutine. The coordinates of dots in the composition of a character with number NC are available in the array IC.

STRETCH SUBROUTINE TO EXTRACT CHARACTER DATA FROM BLOCK 0160

SUBROUTINE XCD160 (NC, IC)

NC = CHARACTER NUMBER (FORTRAN INTEGER)
IC = CHARACTER ARRAY (SYMBOLIC ADDRESS)

The index array and the datum array for a cartographic repertory are packed in a storage area of the subroutine. The coordinates of dots in the composition of a character with number NC are available in the array IC.

STRETCH CATHODE RAY PLOTTING ROUTINE (KXH)

SUBROUTINE CRPLOT (MO, IX, IY, MC)

MO = MODE OF OPERATION (OCTAL)
 IX = X-COORDINATE (FORTRAN INTEGER)
 IY = Y-COORDINATE (FORTRAN INTEGER)
 MC = MATRIX CHARACTER (OCTAL)

The interface between the programmer and the cathode ray printer is buffered in such a way as to achieve maximum efficiency of programming and computation.

Progressive plot instructions are packed in a buffer with a 55(octal) header and with 132 character storage. The storage buffer in the subroutine is unloaded into the printer buffer of MCP whenever (a) the buffer is full, (b) a plot instruction calls for a change of mode from plot to print, (c) the plot instruction calls for a film advance. When positioning without plotting calls for a change of mode from plot to print, the buffer is unloaded, then the positioning without plotting is loaded as the first new instruction in the buffer, the string of characters to be printed is stored in the buffer, and the buffer is unloaded again as soon as (a) the change-of-mode character or the end-of-record character is sensed among the string of characters, or (b) the buffer is full.

S-C 4020

The following programs prepare a tape for off-line utilization on the S-C 4020 cathode ray printer, or prepare systems output for simulation on the S-D 4060 cathode ray printer.

STRETCH SUBROUTINE TO PLOT ON S-C 4020 PRINTER

```
.....
SUBROUTINE PL4020 (MO, IX, IY, LX, LY, MC, NU)
.....
MO = MODE OF OPERATION (OCTAL)
IX = X-COORDINATE (FORTRAN INTEGER)
IY = Y-COORDINATE (FORTRAN INTEGER)
LX = X-COMPONENT (FORTRAN INTEGER)
LY = Y-COMPONENT (FORTRAN INTEGER)
MC = MATRIX CHARACTER (OCTAL)
NU = SYMBOLIC UNIT NUMBER (FORTRAN INTEGER)
```

A binary instruction for the S-C 4020 printer is generated and is stored in a buffer. Whenever the buffer is filled, a record with 144 instructions is written on a tape with unit number NU. The modes of operation MO are as specified in the programmer's manual for the S-C 4020 printer. In the plot character mode, the matrix character with octal number MC is plotted at a point with coordinates IX and IY. In the plot vector mode, a vector with components LX and LY is started from a point with coordinates IX and IY. In the frame advance mode, a frame advance instruction is generated, the last record is padded out with plot blank instructions, and the buffer is closed out.

STRETCH SUBROUTINE TO READ S-C 4020 TAPE

```
.....
SUBROUTINE RD4020 (NU, IX, IY, LX, LY, MC, MO)
.....
NU = UNIT NUMBER (FORTRAN INTEGER)
```

IX = X-COORDINATE (FORTRAN INTEGER)
 IY = Y-COORDINATE (FORTRAN INTEGER)
 LX = X-COMPONENT (FORTRAN INTEGER)
 LY = Y-COMPONENT (FORTRAN INTEGER)
 MC = MATRIX CHARACTER (FORTRAN INTEGER)
 MO = MODE OF OPERATION (FORTRAN INTEGER)

A record of 144 instructions for the S-C 4020 printer is read from an input tape with unit number NU into a buffer whenever necessary to renew the buffer. The next instruction in the buffer is disassembled into FORTRAN integers according to the mode of operation. In the plot character mode, the coordinates of the character are stored in IX and IY and the character number is stored in MC. In the plot vector mode, the coordinates of the start of the vector are stored in IX and IY, while the components of the vector are stored in LX and LY. In any case the mode of operation is stored in MO.

FORTLAN SUBROUTINE TO CONVERT S-C 4020 TAPE TO CRT SYSTEMS OUTPUT

.....
 SUBROUTINE CV4020 (NF)

 NF = NUMBER OF FRAMES (FORTRAN INTEGER)

Instructions for the S-C 4020 printer on tape unit 1 are read into memory through subroutine RD4020. Each instruction for the S-C 4020 printer is converted into instructions for the S-C 4010 printer. In the plot character mode, the character number for the S-C 4020 is translated as far as possible into an equivalent character number for the S-C 4010. In the plot vector mode, each vector on the S-C 4020 is simulated with a line of dots on the S-C 4010. The dots are so spaced that they coalesce into a smooth line. The converted instructions are written out of memory on the systems output tape through subroutine CRPLOT. The subroutine continues to operate until the number of frame advances is equal to NF.

FORTLAN CARTOGRAPHIC SUBROUTINE (S-C 4020)

.....
 SUBROUTINE CTGPHC (LW, KF, CF, CA, NI, NO, GNLTRN)

 LW = WIDTH OF LINE (FORTRAN INTEGER)
 KF = FORMAT ARRAY (SYMBOLIC ADDRESS)
 CF = FIELD ARRAY (SYMBOLIC ADDRESS)
 CA = AREA ARRAY (SYMBOLIC ADDRESS)
 NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
 NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
 GNLTRN = EXTERNAL GNLTRN (AQ, FP)
 AQ = ARGUMENT ARRAY (SYMBOLIC ADDRESS)
 FP = FUNCTION ARRAY (SYMBOLIC ADDRESS)

Map data are read one card record at a time from an input tape with unit number NI. The geographic coordinates in degrees and minutes are converted to floating point values in degrees. Reference is made to an external subroutine GNLTRN to convert geographic coordinates in array AQ to map coordinates in array FP. Any mapping transformation may be used in subroutine GNLTRN. The floating point values of map coordinates are scaled and masked to restrict the plotted line to the bounds as

delimited by array CA for the mapped area and by the array CF for the printer field. The units of FP, CA, CF must be consistent but may be arbitrary otherwise. Plot instructions are generated in accordance with the line width LW and the format KF. The dimensions LW and KF are expressed in raster units. The plot instructions are written through subroutine PL4020 on an output tape with unit number NO. The subroutine continues to operate until a NORC end-of-file is sensed on the input tape.

FORTRAN TYPOGRAPHIC SUBROUTINE (S-C 4020)

```

.....
SUBROUTINE TPGPHC (NL, NI, NO, AI, AD)
.....
NL = 0 FOR NO PRINTING OF UNDERLINE LEVELS
NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
AI = INDEX ARRAY (SYMBOLIC ADDRESS)
AD = DATUM ARRAY (SYMBOLIC ADDRESS)

```

Control data are read one card record at a time from an input tape with unit number NI.

In the PLOT mode, shaped characters from the character matrix, stroked characters from the index and datum arrays AI and AD, and arbitrary vectors are plotted at any coordinates and with any scaling as specified by the control data.

In the PRINT mode, textual data are plotted and arbitrary vectors are ruled as specified by functional data. Ligaturization, capitalization, and justification of the textual data are executed under control of the functional data. Printing of underline levels for diagnostic purposes is under the control of the parameter NL.

Plot instructions are written through subroutine PL4020 on an output tape with unit number NO. A frame advance instruction is generated whenever FRAME is sensed on a control card. Operation is terminated whenever RETURN is sensed on a control card.

S-D 4060

The following programs prepare a tape for off-line utilization on the S-D 4060 cathode ray printer, or prepare systems output for simulation on the S-D 4060 cathode ray printer.

STRETCH SUBROUTINE TO PLOT ON S-D 4060 PRINTER

```

.....
SUBROUTINE PL4060 (MO, IQ, NU)
.....
MO = MODE OF OPERATION (FORTRAN INTEGER)
IQ = INPUT META NUMBER (FORTRAN INTEGER)
NU = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
IF MO = 1, IQ = F, WORD = F
IF MO = 2, IQ = C, WORD = NULL, C
IF MO = 3, IQ = X, WORD = X
IF MO = 3, IQ = Y, WORD = Y
IF MO = 4, BUFFER IS CLOSED

```

A 16-bit word of meta language for the S-D 4060 printer is generated and is stored in a buffer. Whenever the buffer is filled, a record with 288 words is written on a tape

with unit number NU. In the composition of a meta function string, several calls are made to PL4060 with appropriate values of MO and IQ. When the buffer is closed, the last record is padded out with null bytes.

STRETCH SUBROUTINE TO READ S-D 4060 TAPE

.....
 SUBROUTINE RD4060 (MO, IQ, NU)

MO = MODE OF OPERATION (FORTRAN INTEGER)
 IQ = OUTPUT META NUMBER (FORTRAN INTEGER)
 NU = INPUT TAPE NUMBER (FORTRAN INTEGER)
 IF MO = 1, IQ = F, WORD = *, F
 IF MO = 2, IQ = C, WORD = NULL, C
 IF MO = 3, IQ = X, WORD = X
 IF MO = 3, IQ = Y, WORD = Y
 IF MO = 4, BUFFER IS CLOSED

A record of 288 words of meta language for the S-D 4060 printer is read from an input tape with unit number NU into a buffer whenever necessary to renew the buffer. The next word in the buffer is interpreted according to the value of MO. In the decomposition of a meta function string, several calls are made to RD4060 with anticipated values of MO.

FORTRAN SUBROUTINE TO CONVERT S-D 4060 TAPE TO CRT SYSTEMS OUTPUT

.....
 SUBROUTINE CV4060 (NF)

NF = NUMBER OF FRAMES (FORTRAN INTEGER)

Instructions for the S-D 4060 printer on tape unit 1 are read into memory through subroutine RD4060. Each instruction for the S-D 4060 printer is converted into instructions for the S-C 4010 printer. In the plot character mode, the character number for the S-D 4060 is translated as far as possible into an equivalent character number for the S-C 4010. In the plot vector mode, each vector on the S-D 4060 is simulated with a line of dots on the S-C 4010. The dots are so spaced that they coalesce into a smooth line. The converted instructions are written out of memory on the systems output tape through subroutine CRPLOT. The subroutine continues to operate until the number of frame advances is equal to NF.

FORTRAN CARTOGRAPHIC SUBROUTINE (S-D 4060)

.....
 SUBROUTINE CTGPHC (LW, KF, CF, CA, NI, NO, GNLTRN)

LW = WIDTH OF LINE (FORTRAN INTEGER)
 KF = FORMAT ARRAY (SYMBOLIC ADDRESS)
 CF = FIELD ARRAY (SYMBOLIC ADDRESS)
 CA = AREA ARRAY (SYMBOLIC ADDRESS)
 NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
 NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
 EXTERNAL GNLTRN (AQ, FP)
 AQ = ARGUMENT ARRAY (SYMBOLIC ADDRESS)
 FP = FUNCTION ARRAY (SYMBOLIC ADDRESS)

Map data are read one card record at a time from an input tape with unit number NI. The geographic coordinates in degrees and minutes are converted to floating point values in degrees. Reference is made to an external subroutine GNLTRN to convert geographic coordinates in array AQ to map coordinates in array EP. Any mapping transformation may be used in subroutine GNLTRN. The floating point values of map coordinates are scaled and masked to restrict the plotted line to the bounds as delimited by array CA for the mapped area and by the array CF for the printer field. The units of EP, CA, CF must be consistent but may be arbitrary otherwise. Plot instructions are generated in accordance with the line width LW and the format KF. The dimensions LW and KF are expressed in raster units. The plot instructions are written through subroutine PL4060 on an output tape with unit number NO. The subroutine continues to operate until a NORC end-of-file is sensed on the input tape.

FORTTRAN TYPOGRAPHIC SUBROUTINE (S-D 4060)

.....
 SUBROUTINE TPGPHC (NL, NI, NO, AI, AD)

NL = 0 FOR NO PRINTING OF UNDERLINE LEVELS
 NI = INPUT TAPE NUMBER (FORTRAN INTEGER)
 NO = OUTPUT TAPE NUMBER (FORTRAN INTEGER)
 AI = INDEX ARRAY (SYMBOLIC ADDRESS)
 AD = DATUM ARRAY (SYMBOLIC ADDRESS)

Control data are read one card record at a time from an input tape with unit number NI.

In the PLOT mode, shaped characters from the character matrix, stroked characters from the index and datum arrays AI and AD, and arbitrary vectors are plotted at any coordinates and with any scaling as specified by the control data.

In the PRINT mode, textual data are plotted and arbitrary vectors are ruled as specified by functional data. Ligaturization, capitalization, and justification of the textual data are executed under control of the functional data. Printing of underline levels for diagnostic purposes is under the control of the parameter NL.

Plot instructions are written through subroutine PL4060 on an output tape with unit number NO. A frame advance instruction is generated whenever FRAME is sensed on a control card. Operation is terminated whenever RETURN is sensed on a control card.

FORMATS

The repertory of formats for the cartographic subroutines is given in the following list.

KF(1) = LENGTH OF DASH
 KF(2) = LENGTH OF SPACE
 KF(3) = LENGTH OF DASH
 KF(4) = LENGTH OF SPACE
 KF(5) = LENGTH OF DASH
 KF(6) = LENGTH OF SPACE
 KF(7) = LENGTH OF DASH
 KF(8) = LENGTH OF SPACE
 CF(1) = LEFT EDGE OF PRINTER FIELD
 CF(2) = RIGHT EDGE OF PRINTER FIELD

CF(3) = UPPER EDGE OF PRINTER FIELD
 CF(4) = LOWER EDGE OF PRINTER FIELD
 CA(1) = LEFT EDGE OF MAPPED AREA
 CA(2) = RIGHT EDGE OF MAPPED AREA
 CA(3) = UPPER EDGE OF MAPPED AREA
 CA(4) = LOWER EDGE OF MAPPED AREA
 AQ(1) = LATITUDE (DEGREES)
 AQ(2) = LONGITUDE (DEGREES)
 FP(1) = X-COORDINATE (MAP UNITS)
 FP(2) = Y-COORDINATE (MAP UNITS)

The plotting of a line element for the argument AQ is bypassed if no function FP is computed by subroutine GNLTRN.

MNEMONICS

The repertory of functional codes for the typographic subroutines is given in the following list, where SSSS, XXXX, YYYY represent signed integers and NN, NNNN represent unsigned integers. The notation SSSS is used for a component of the scaling matrix, the notation XXXX is used for a reset or increment of X while the notation YYYY is used for a reset or increment of Y. The notation NN is used for a column number while the notation NNNN is used for a code number or for a character number. In the plot mode, a numerical field may be blank, but in the print mode, each numerical field must be occupied.

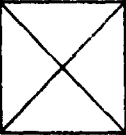
PLOT	PLOT MODE
OC,XXXX,YYYY,	ORIGIN OF COORDINATES
MS,SSSS,SSSS,SSSS,SSSS,	MATRIX OF SCALING
XY,XXXX,YYYY,	RESETTING OF COORDINATES
OK,NNNN,	ORIENTATION OF CHARACTER
SK,NNNN,	SIZE OF CHARACTER
CK,NNNN,	CASE OF CHARACTER
WL,NNNN,	WIDTH OF LINE
PC,OMMM, OR PC,NNNN,	PLOTTING OF CHARACTER
PV,XXXX,YYYY,	PLOTTING OF VECTOR
.	RECYCLING WITHOUT CHANGE OF MODE
.	RECYCLING WITH CHANGE OF MODE
PRINT	PRINT MODE
OC,XXXX,YYYY,	ORIGIN OF COORDINATES
MS,SSSS,SSSS,SSSS,SSSS,	MATRIX OF SCALING
MA,XXXX,XXXX,YYYY,YYYY,	MARGIN ALLOWANCE
IS,XXXX,YYYY,	INTERVAL OF SPACING
XY,XXXX,YYYY,	RESETTING OF X AND Y
HY,XXXX,YYYY,	INCREMENTING OF X AND RESETTING OF Y
XV,XXXX,YYYY,	RESETTING OF X AND INCREMENTING OF Y
HV,XXXX,YYYY,	INCREMENTING OF X AND Y
OK,NNNN,	ORIENTATION OF CHARACTER
SK,NNNN,	SIZE OF CHARACTER
CK,NNNN,	CASE OF CHARACTER
WL,NNNN,	WIDTH OF LINE

NJ	NONJUSTIFICATION
AJ	AUTOJUSTIFICATION
PN	PRINCIPAL LEVEL AT NORMAL SIZE
PI	PRINCIPAL LEVEL AT INDEXICAL SIZE
SB	SUBSCRIPT LEVEL AT INDEXICAL SIZE
SP	SUPERSCRIPIT LEVEL AT INDEXICAL SIZE
(NN)	CONTINUATION
NNNN,	CHARACTER NUMBER
LC	LOWER CASE
LR	LOWER CASE ROMAN
LG	LOWER CASE GREEK
LI	LOWER CASE ITALIC
LS	LOWER CASE SCRIPT
UC	UPPER CASE
UR	UPPER CASE ROMAN
UG	UPPER CASE GREEK
UI	UPPER CASE ITALIC
US	UPPER CASE SCRIPT
KR	CARTOGRAPHIC ROMAN
KG	CARTOGRAPHIC GREEK
SR	SIMPLEX ROMAN
SG	SIMPLEX GREEK
SS	SIMPLEX SCRIPT
DR	DUPLEX ROMAN
CR	COMPLEX ROMAN
CG	COMPLEX GREEK
CI	COMPLEX ITALIC
CS	COMPLEX SCRIPT
CC	COMPLEX CYRILLIC
GE	GOTHIC ENGLISH
GI	GOTHIC ITALIAN
GG	GOTHIC GERMAN
VP	VARIANT PRIMARY
VS	VARIANT SECONDARY
VT	VARIANT TERTIARY
VQ	VARIANT QUATERNARY
QA(NN,NN/NN,NN) OR QA(NN,NN\$XXXX)	QUADING FOR ALIGNMENT
QL(NN,NN/NN,NN) OR QL(NN,NN\$XXXX)	QUADING TO LEFT
QR(NN,NN/NN,NN) OR QR(NN,NN\$XXXX)	QUADING TO RIGHT
QC(NN,NN/NN,NN) OR QC(NN,NN\$XXXX)	QUADING FOR CENTERING
RL(LL/NN,NN)	RULING OF LINE
RV(NN,NN)	RULING OF VECTOR
.	RECYCLING WITHOUT CHANGE OF MODE
	RECYCLING WITH CHANGE OF MODE
FRAME	FRAME ADVANCE
RETURN	END OF OPERATION

APPENDIX B

CARD PUNCH CODE

SIXTY-FOUR CHARACTER SET

	0	1	2	3	4	5	6	7
0		1 1-1	2 2-2	3 3-3	4 4-4	5 5-5	6 6-6	7 7-7
1	8 8-8	9 9-9	0 0-0	= 8-3	@ 9-4	: 9-6	> 9-8	≅ 9-1
2		/ 0-1	S 9-2	T 0-3	U 0-4	V 0-5	W 0-6	X 0-7
3	Y 0-8	Z 0-9	≠ 0-0-2	, 0-0-3	(0-0-4	' 0-0-5	" 0-0-6	° 0-0-7
4	- 11	J 11-1	K 11-2	L 11-3	M 11-4	N 11-5	O 11-6	P 11-7
5	Q 11-8	R 11-9	! 11-0	\$ 11-0-3	* 11-0-4] 11-0-5	; 11-0-6	& 11-0-7
6	+ 12	A 12-1	B 12-2	C 12-3	D 12-4	E 12-5	F 12-6	G 12-7
7	H 12-8	I 12-9	? 12-0	. 12-0-3) 12-0-4	[12-0-5	< 12-0-6	≅ 12-0-7

APPENDIX C

FORTRAN TRANSLITERATIONS

FORTRAN	CARTOGRAPHIC ROMAN		SIMPLEX ROMAN		SIMPLEX SCRIPT	
	VP, VS	VT, VQ	VP, VS, VT, VQ		VP, VS, VT, VQ	
	KR	KR	UCSR	LCSR	UCSS	LCSS
A	A	A	A	a	A	a
B	B	B	B	b	B	b
C	C	C	C	c	C	c
D	D	D	D	d	D	d
E	E	E	E	e	E	e
F	F	F	F	f	F	f
G	G	G	G	g	G	g
H	H	H	H	h	H	h
I	I	I	I	i	I	i
J	J	J	J	j	J	j
K	K	K	K	k	K	k
L	L	L	L	l	L	l
M	M	M	M	m	M	m
N	N	N	N	n	N	n
O	O	O	O	o	O	o
P	P	P	P	p	P	p
Q	Q	Q	Q	q	Q	q
R	R	R	R	r	R	r
S	S	S	S	s	S	s
T	T	T	T	t	T	t
U	U	U	U	u	U	u
V	V	V	V	v	V	v
W	W	W	W	w	W	w
X	X	X	X	x	X	x
Y	Y	Y	Y	y	Y	y
Z	Z	Z	Z	z	Z	z

FORTRAN	CARTOGRAPHIC GREEK		SIMPLEX GREEK			
	VP	VS	VP		VS	
	KG	KG	UCSG	LCSG	UCSG	LCSG
A	A	A	A	α	A	α
B	B	B	B	β	B	β
G	Γ	Γ	Γ	γ	Γ	γ
D	Δ	Δ	Δ	δ	Δ	δ
E	E	H	E	ε	H	η
Z	Z	Z	Z	ζ	Z	ζ
TH	Θ	T	Θ	θ	T	τ
I	I	I	I	ι	I	ι
K	K	K	K	κ	K	κ
L	Λ	Λ	Λ	λ	Λ	λ
M	M	M	M	μ	M	μ
N	N	N	N	ν	N	ν
X	Ξ	Ξ	Ξ	ξ	Ξ	ξ
O	O	Ω	O	ο	Ω	ω
P	Π	Π	Π	π	Π	π
R	P	P	P	ρ	P	ρ
S	Σ	Σ	Σ	σ	Σ	ς
T	T	T	T	τ	T	τ
U, V	T	T	T	υ	T	υ
PH	Φ	Π	Φ	φ	Π	π
CH	X	X	X	χ	X	χ
PS	Ψ	ΠΣ	Ψ	ψ	ΠΣ	πς

FORTRAN	CARTOGRAPHIC GREEK		SIMPLEX GREEK			
	VT	VQ	VT		VQ	
	KG	KG	UCSG	LCSG	UCSG	LCSG
A	A	A	A	α	A	α
B	B	B	B	β	B	β
G	Γ	Γ	Γ	γ	Γ	γ
D	Δ	Δ	Δ	δ	∇	θ
E	E	E	E	ε	E	ε
Z	Z	Z	Z	ζ	Z	ζ
H	H	H	H	η	H	η
O	Θ	Θ	Θ	θ	Θ	θ
I	I	I	I	ι	I	ι
K	K	K	K	κ	K	κ
L	Λ	Λ	Λ	λ	Λ	λ
M	M	M	M	μ	M	μ
N	N	N	N	ν	N	ν
X	Ξ	Ξ	Ξ	ξ	Ξ	ξ
O	O	O	O	ο	O	ο
P	Π	Π	Π	π	Π	π
R	P	P	P	ρ	P	ρ
S	Σ	Σ	Σ	σ	Σ	σ
T	T	T	T	τ	T	τ
U	T	T	T	υ	T	υ
F	Φ	Φ	Φ	φ	Φ	φ
C	Χ	Χ	Χ	χ	Χ	χ
Y	Ψ	Ψ	Ψ	ψ	Ψ	ψ
W	Ω	Ω	Ω	ω	Ω	ω

FORTRAN	COMPLEX ROMAN				COMPLEX ROMAN			
	VP		VS, VT, VO		VP		VS, VT, VO	
	PNUR	PNLR	PTUR	PTLR	PNUR	PNLR	PNUR	PNLR
A	A	a	A	a	A	a	A	a
B	B	b	B	b	B	b	B	b
C	C	c	C	c	C	c	C	c
D	D	d	D	d	D	d	D	d
E	E	e	E	e	E	e	E	e
F	F	f	F	f	F	f	F	f
G	G	g	G	g	G	g	G	g
H	H	h	H	h	H	h	H	h
I	I	i	I	i	I	i	I	i
J	J	j	J	j	J	j	J	j
K	K	k	K	k	K	k	K	k
L	L	l	L	l	L	l	L	l
M	M	m	M	m	M	m	M	m
N	N	n	N	n	N	n	N	n
O	O	o	O	o	O	o	O	o
P	P	p	P	p	P	p	P	p
Q	Q	q	Q	q	Q	q	Q	q
R	R	r	R	r	R	r	R	r
S	S	s	S	s	S	s	S	s
T	T	t	T	t	T	t	T	t
U	U	u	U	u	U	u	U	u
V	V	v	V	v	V	v	V	v
W	W	w	W	w	W	w	W	w
X	X	x	X	x	X	x	X	x
Y	Y	y	Y	y	Y	y	Y	y
Z	Z	z	Z	z	Z	z	Z	z
FF	FF	ff	FF	ff	FF	ff	FF	ff
FI	FI	fi	FI	fi	FI	fi	FI	fi
FL	FL	fl	FL	fl	FL	fl	FL	fl
FFI	FFI	ffi	FFI	ffi	FFI	ffi	FFI	ffi
FFL	FFL	ffl	FFL	ffl	FFL	ffl	FFL	ffl

FORTRAN	COMPLEX ITALIC				COMPLEX ITALIC			
	VP		VS, VT, VQ		VP		VS, VT, VQ	
	PNLJ	PLJ	PNLI	PLI	PNLI	PNLI	PNLI	PNLI
A	A	a	A	a	A	a	A	a
B	B	b	B	b	B	b	B	b
C	C	c	C	c	C	c	C	c
D	D	d	D	d	D	d	D	d
E	E	e	E	e	E	e	E	e
F	F	f	F	f	F	f	F	f
G	G	g	G	g	G	g	G	g
H	H	h	H	h	H	h	H	h
I	I	i	I	i	I	i	I	i
J	J	j	J	j	J	j	J	j
K	K	k	K	k	K	k	K	k
L	L	l	L	l	L	l	L	l
M	M	m	M	m	M	m	M	m
N	N	n	N	n	N	n	N	n
O	O	o	O	o	O	o	O	o
P	P	p	P	p	P	p	P	p
Q	Q	q	Q	q	Q	q	Q	q
R	R	r	R	r	R	r	R	r
S	S	s	S	s	S	s	S	s
T	T	t	T	t	T	t	T	t
U	U	u	U	u	U	u	U	u
V	V	v	V	v	V	v	V	v
W	W	w	W	w	W	w	W	w
X	X	x	X	x	X	x	X	x
Y	Y	y	Y	y	Y	y	Y	y
Z	Z	z	Z	z	Z	z	Z	z
FF	FF	ff	FF	ff	FF	ff	FF	ff
FI	FI	fi	FI	fi	FI	fi	FI	fi
FL	FL	fl	FL	fl	FL	fl	FL	fl
FFI	FFI	ffi	FFI	ffi	FFI	ffi	FFI	ffi
FFL	FFL	ffl	FFL	ffl	FFL	ffl	FFL	ffl

FORTRAN	COMPLEX GREEK				COMPLEX GREEK			
	VP		VS		VP		VS	
	PIUG	PILG	PIUG	PILG	PNUG	PNLG	PNUG	PNLG
A	Α	α	Α	α	Α	α	Α	α
B	Β	β	Β	β	Β	β	Β	β
G	Γ	γ	Γ	γ	Γ	γ	Γ	γ
D	Δ	δ	Δ	δ	Δ	δ	Δ	δ
E	Ε	ε	Η	η	Ε	ε	Η	η
Z	Ζ	ζ	Ζ	ζ	Ζ	ζ	Ζ	ζ
TH	Θ	θ	Τ	τ	Θ	θ	Τ	τ
I	Ι	ι	Ι	ι	Ι	ι	Ι	ι
K	Κ	κ	Κ	κ	Κ	κ	Κ	κ
L	Λ	λ	Λ	λ	Λ	λ	Λ	λ
M	Μ	μ	Μ	μ	Μ	μ	Μ	μ
N	Ν	ν	Ν	ν	Ν	ν	Ν	ν
X	Ξ	ξ	Ξ	ξ	Ξ	ξ	Ξ	ξ
O	Ο	ο	Ω	ω	Ο	ο	Ω	ω
P	Π	π	Π	π	Π	π	Π	π
R	Ρ	ρ	Ρ	ρ	Ρ	ρ	Ρ	ρ
S	Σ	σ	Σ	ς	Σ	σ	Σ	ς
T	Τ	τ	Τ	τ	Τ	τ	Τ	τ
U, V	Υ	υ	Υ	υ	Υ	υ	Υ	υ
PH	Φ	φ	Π	π	Φ	φ	Π	π
CH	Χ	χ	Υ	ι	Χ	χ	Χ	χ
PS	Ψ	ψ	ΠΣ	πς	Ψ	ψ	ΠΣ	πς

FORTRAN	COMPLEX GREEN				COMPLEX GREEN			
	VT		VG		VT		VG	
	PJUG	PLG	PJUG	PLG	PJUG	PLG	PJUG	PLG
A	Α	α	Α	α	Α	α	Α	α
B	Β	β	Β	β	Β	β	Β	β
G	Γ	γ	Γ	γ	Γ	γ	Γ	γ
D	Δ	δ	Δ	δ	Δ	δ	Δ	δ
E	Ε	ε	Ε	ε	Ε	ε	Ε	ε
Z	Ζ	ζ	Ζ	ζ	Ζ	ζ	Ζ	ζ
H	Η	η	Η	η	Η	η	Η	η
Θ	Θ	θ	Θ	θ	Θ	θ	Θ	θ
I	Ι	ι	Ι	ι	Ι	ι	Ι	ι
K	Κ	κ	Κ	κ	Κ	κ	Κ	κ
L	Λ	λ	Λ	λ	Λ	λ	Λ	λ
M	Μ	μ	Μ	μ	Μ	μ	Μ	μ
N	Ν	ν	Ν	ν	Ν	ν	Ν	ν
X	Ξ	ξ	Ξ	ξ	Ξ	ξ	Ξ	ξ
O	Ο	ο	Ο	ο	Ο	ο	Ο	ο
P	Π	π	Π	π	Π	π	Π	π
R	Ρ	ρ	Ρ	ρ	Ρ	ρ	Ρ	ρ
S	Σ	σ	Σ	σ	Σ	σ	Σ	σ
T	Τ	τ	Τ	τ	Τ	τ	Τ	τ
U	Υ	υ	Υ	υ	Υ	υ	Υ	υ
F	Φ	φ	Φ	φ	Φ	φ	Φ	φ
C	Χ	χ	Χ	χ	Χ	χ	Χ	χ
Y	Ψ	ψ	Ψ	ψ	Ψ	ψ	Ψ	ψ
W	Ω	ω	Ω	ω	Ω	ω	Ω	ω

FORTRAN	COMPLEX CYRILIC			
	VP		VE	
	UCCC	LCCC	UCCC	LCCC
A	А	а	А	а
B	Б	б	Б	б
V	В	в	В	в
G	Г	г	Г	г
D	Д	д	Д	д
E	Е	е	Э	э
ZH	Ж	ж	З	з
Z	З	з	И	и
I	И	и	Й	й
X	К	к	К	к
L	Л	л	Л	л
M	М	м	М	м
N	Н	н	Н	н
O	О	о	О	о
P	П	п	П	п
R	Р	р	Р	р
S	С	с	С	с
T	Т	т	Т	т
U	У	у	У	у
F	Ф	ф	Ф	ф
KH	Х	х	К	к
TS	Ц	ц	ТС	ТС
CH	Ч	ч	Ч	ч
SH	Ш	ш	Ш	ш
SHCH	Щ	щ	ШЧ	шч
Y	Ы	ы	Ы	ы
YU	Ю	ю	ЫУ	ыу
YA	Я	я	ЫА	ыа
.	Ь	ь	Ъ	ъ

FORTAN	DUPLEX ROMAN		COMPLEX SCRIPT		GOTHIC ENGLISH		GOTHIC ITALIAN	
	VP, VS, VT, VQ		VP, VS, VT, VQ		VP, VS		VP, VS	
	UCDR	LCDR	UCCS	LCCS	UCGE	LCGE	ULGI	LCGI
A	A	a	A	a	A	a	H	a
B	B	b	B	b	B	b	B	b
C	C	c	C	c	C	c	C	c
D	D	d	D	d	D	d	D	d
E	E	e	E	e	E	e	E	e
F	F	f	F	f	F	f	F	f
G	G	g	G	g	G	g	G	g
H	H	h	H	h	H	h	H	h
I	I	i	I	i	I	i	I	i
J	J	j	J	j	J	j	J	j
K	K	k	K	k	K	k	K	k
L	L	l	L	l	L	l	L	l
M	M	m	M	m	M	m	M	m
N	N	n	N	n	N	n	N	n
O	O	o	O	o	O	o	O	o
P	P	p	P	p	P	p	P	p
Q	Q	q	Q	q	Q	q	Q	q
R	R	r	R	r	R	r	R	r
S	S	s	S	s	S	s	S	s
T	T	t	T	t	T	t	T	t
U	U	u	U	u	U	u	U	u
V	V	v	V	v	V	v	V	v
W	W	w	W	w	W	w	W	w
X	X	x	X	x	X	x	X	x
Y	Y	y	Y	y	Y	y	Y	y
Z	Z	z	Z	z	Z	z	Z	z

FORTRAN	GOTHIC GERMAN			
	VP		VS	
	UCGG	LCGG	UCGG	LCGG
A	ⱥ	ⱦ	ⱥ	ⱦ
B	Ⱨ	ⱨ	Ⱨ	ⱨ
C	Ⱪ	ⱪ	Ⱪ	ⱪ
D	ⱬ	Ɑ	ⱬ	Ɑ
E	Ɱ	Ɐ	Ɱ	Ɐ
F	ⱱ	Ⱳ	ⱱ	Ⱳ
G	ⱳ	ⱴ	ⱳ	ⱴ
H	ⱶ	ⱷ	ⱶ	ⱷ
I	ⱹ	ⱺ	ⱹ	ⱺ
J	ⱻ	ⱼ	ⱻ	ⱼ
K	ⱽ	Ȿ	ⱽ	Ȿ
L	Ɀ	Ɀ	Ɀ	Ɀ
M	Ɀ	m	Ɀ	m
N	Ɀ	n	Ɀ	n
O	Ɀ	o	Ɀ	o
P	Ɀ	p	Ɀ	p
Q	Ɀ	q	Ɀ	q
R	Ɀ	r	Ɀ	r
S	Ɀ	ŕ	Ɀ	s
T	Ɀ	t	Ɀ	t
U	Ɀ	u	Ɀ	u
V	Ɀ	v	Ɀ	v
W	Ɀ	w	Ɀ	w
X	Ɀ	x	Ɀ	x
Y	Ɀ	y	Ɀ	y
Z	Ɀ	z	Ɀ	z
SS	Ɀ	ß	Ɀ	ſſ
TZ	Ɀ	tz	Ɀ	tz
Ä	Ɀ	ä	Ɀ	ä
Ö	Ɀ	ö	Ɀ	ö
Ü	Ɀ	ü	Ɀ	ü

FORTRAN	NUMERALS				
	CARTOGRAPHIC	SIMPLEX	COMPLEX	COMPLEX	GOTHIC
	KR, KG	SR, SG, SS	PI	PN	GE
0	0	0	0	0	0
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
8	8	8	8	8	8
9	9	9	9	9	9

FORTRAN	CARTOGRAPHIC SIGNS				SIMPLEX SIGNS			
	VP	VS	VT	VQ	VP	VS	VT	VQ
	UC, LC	UC, LC	UC, LC	UC, LC	UC, LC	UC, LC	UC, LC	UC, LC
.	.	:	:	.	.	:	:	:
.	.	?	!	"	.	?	!	"
(((((((((
)))))))))
-	-	-	-	-	-	-	-	-
+	+	+	+	+	+	+	+	+
*	*	.	x	.	*	.	x	o
/	/	/	/	/	/	/	/	/
=	=	=	=	=	=	=	=	=
\$	\$	#		□	\$	#		□

FORTRAN	INDEXICAL COMPLEX SIGNS							
	VP		VS		VT		VQ	
	UC	LC	UC	LC	UC	LC	UC	LC
,	,	,	;	;	:	:	'	'
.	.	.	?	?	!	!	'	'
((([[(({	}
)))]]))	}	}
-	-	-	c	~	-	-	→	↑
+	+	+	u	&	+	+	±	≠
*	*	*	u	∞	x	.	>	<
/	/	/	u	%)	(
=	=	=	ε	≠	=	=	≥	≤
:	:	:	ε	#	√	√	∫	∫
•	•	•	‡	'	↑	"	∞	•

FORTRAN	NORMAL COMPLEX SIGNS							
	VP		VS		VT		VQ	
	UC	LC	UC	LC	UC	LC	UC	LC
'	,	,	;	;	:	:	,	,
.	.	.	?	?	!	!	.	.
((([[(({	{
)))]]))	}	}
-	-	-	C	~	-	-	→	←
+	+	+	U	&	+	+	±	≠
*	*	*	∩	α	x	.	>	<
/	/	/	∪	%			>	<
=	=	=	∈	≠	=	=	≅	≅
\$	\$	\$	E	#	√	√	∫	∫
@	@	@	\$.	†	"	∞	°

APPENDIX D

MAPS

The World

Two maps of the World are presented herewith to illustrate the use of the cartographic subroutine.

Mercator Projection

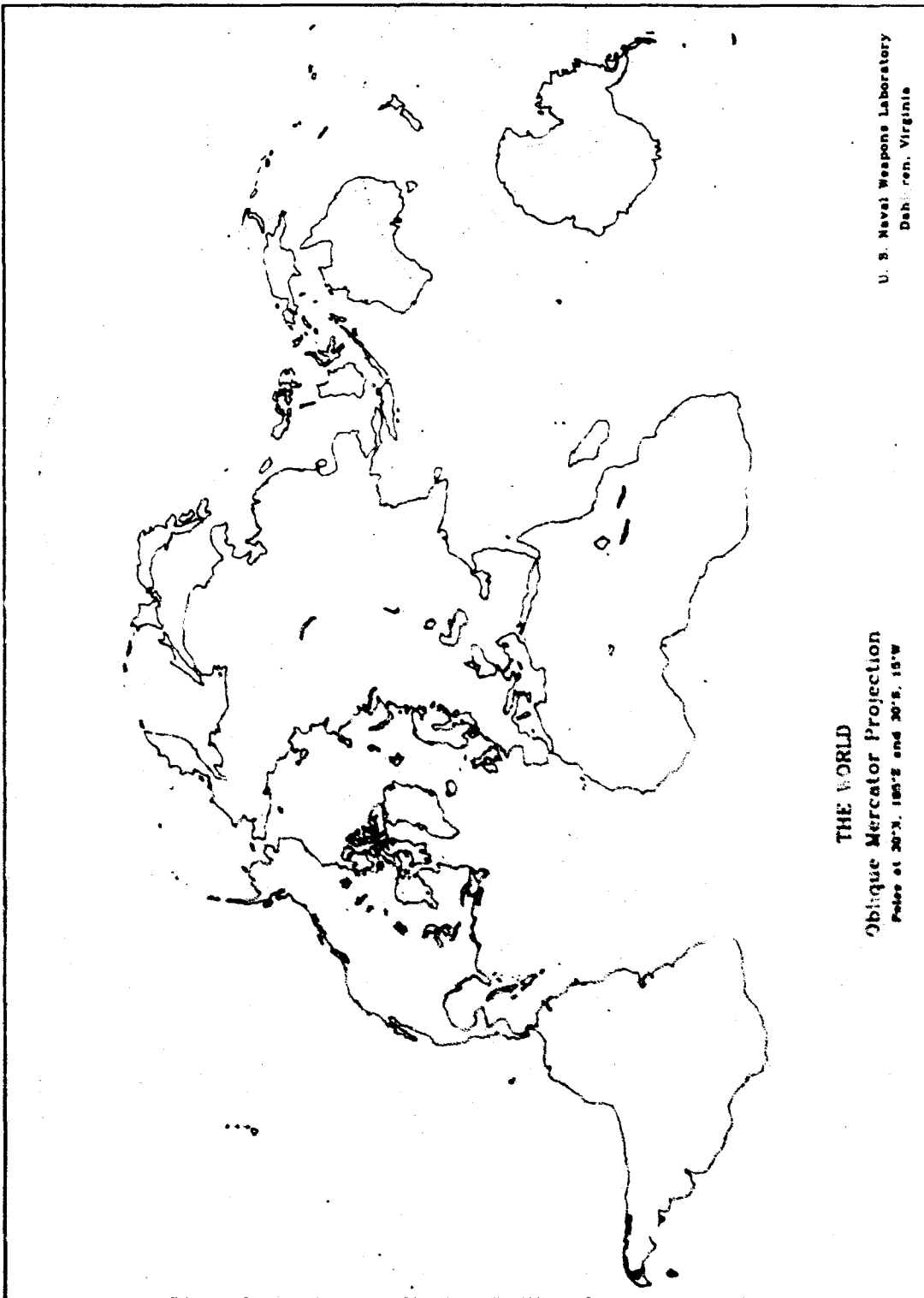
The first map is an oblique Mercator projection which was prepared at the suggestion of Mr. Bernard Smith¹. The poles of the Mercator projection are so situated as to be at the greatest possible distance from land. This gives some long range distortion of parallels and meridians, but it gives less local distortion of the land areas than the conventional Mercator projection.

Perspective Projection

The second map is a perspective projection of the Earth as it was photographed from the Moon during the Apollo 8 mission. The instant of photography was deduced with the aid of the flight log which has been published by Lt. Gen. Phillips².

References

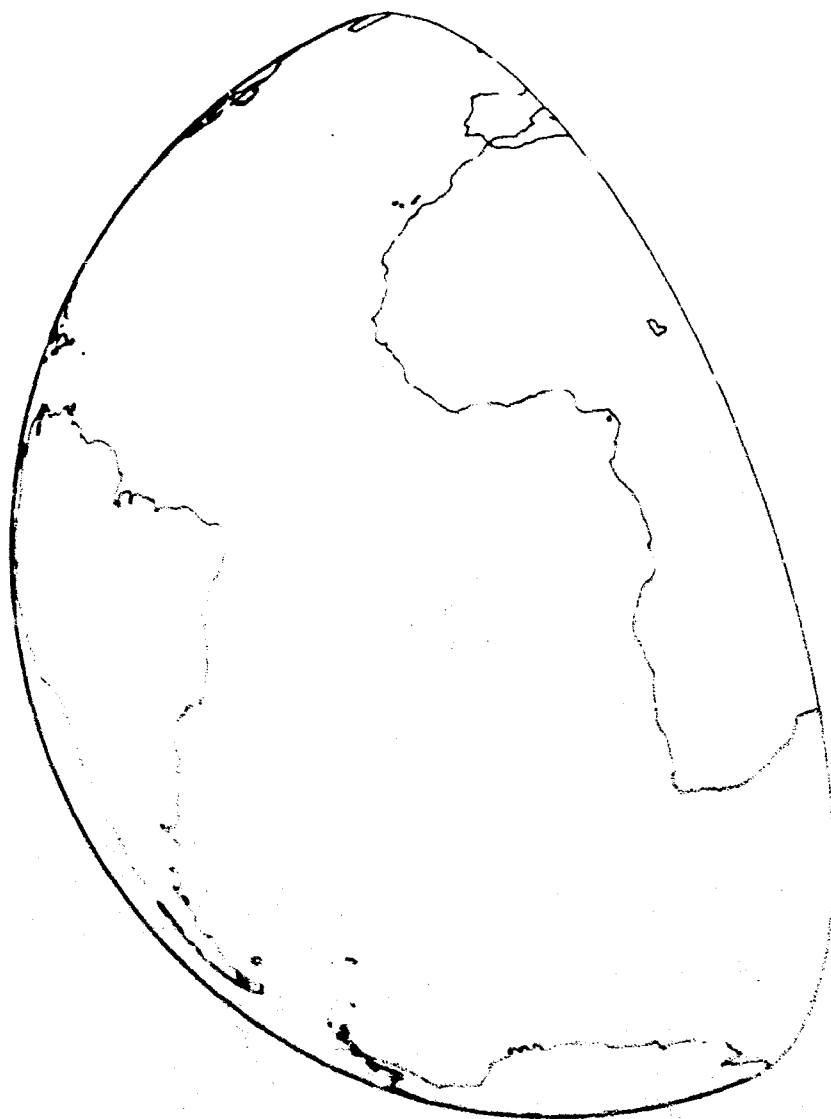
1. *Computers adapted for Cartography*
The Laboratory Log, Naval Weapons Laboratory, 5 August 1966.
2. "A Most Fantastic Voyage"
Lt. Gen. S. C. Phillips, National Geographic Magazine, 135, 593 (1969)



THE WORLD
Oblique Mercator Projection
Poles at 30°N, 180°E and 30°S, 15°W

U. S. Naval Weapons Laboratory
Dahlgren, Virginia

FOURTH EARTHRISE DURING APOLLO 9 MISSION



REFERENCE: NATIONAL GEOGRAPHIC MAGAZINE

APPENDIX E

TEXT

THE EVOLUTION OF WRITING

Introduction

Of the principal ancient writing systems, only the Chinese has continued without interruption into modern times. The ancient Egyptian and Sumerian writing systems were lost in antiquity until trilingual texts such as the Rosetta Stone in Egypt and the Behistun Inscription in Persia gave the key to decipherment. The romantic story of the decipherment of the lost languages has been recorded in various texts, and the results of decipherment have been documented in a series of glossaries and dictionaries. A small list of reference material is given herewith in the Bibliography.

Samples of ancient writing have been digitized and are displayed in Figures 1 through 3, while the active lifetimes of the principal writing systems are illustrated in Figure 4. The actual lifetimes are known only approximately because each writing system tends to rise gradually to a peak and to fall gradually into disuse. The instants of creation or termination are indefinite.

Evolution

Prior to the invention of a system of writing, messages were conveyed by pictures which illustrated scenes. The first writing began when the pictures were so arranged in a line as to convey a sequence of events.

The invention of a system of writing has occurred only a few times in the history of mankind. It is not easy to establish a system. From the beginning it must be mnemonic and useful in many ways. There must be enough people who are willing to learn and to use the system. Their cooperation is improved no doubt by a decree of an emperor. It may be that there is a critical number of people who must learn the system before other people realize that it is to their advantage also to learn the system.

Conversely, it is not easy to change a system of writing once it has become established. Aside from the natural disinclination of people to make changes, there are factors which tend to stabilize and to perpetuate the system through millennia. Any change in inherent symbolism must be an obvious simplification or a sure clarification before it will be acceptable to the critical number of people who can make the change permanent. A system of writing may persist long after the annihilation of the system of politics under which it first appeared.

Although the inherent symbolism of a system of writing tends to remain constant, the style of writing can vary greatly. Fanciful notions and errors in interpretation by scribes have led to changes in symbols. The changes sometimes have been meaningless deviations, but sometimes have had poetic or logical interpretations. When scribes have been in a hurry they have created cursive styles of writing which appear very different from the original calligraphy. The invention of new instruments of writing has had a profound influence on the style of writing.

Major changes in the inherent symbolism have occurred primarily when a system of writing has been adopted by a people who previously have been illiterate. The introduction of a new system of writing often has accompanied the introduction of a new system of religion.

Pictographic Stage

The first stage of evolution was pictographic. The picture of an object could be used

as the symbol of the object, in which case it became a pictogram. The picture of the object could stand for an idea which is associated with the object, in which case it became an ideogram. The picture of the object could stand for the sound which was spoken in reference to the object, in which case it became a phonogram. Thus the symbol ☉ is a pictogram when it represents the sun, but it is an ideogram when it represents a day, and it is a phonogram when it represents the syllable *hrw*. When a symbol represents a syllable it is a syllabogram, while if the symbol represents an entire word it is a logogram. Some symbols represent short words and could be combined phonetically to express longer words. A limited number of symbols were used as determinatives or radicals which acted as classifiers when they were included with other symbols. Thus the symbol for wood or tree was combined with other symbols to designate things made of wood or to distinguish different kinds of tree. The determinatives did not participate in the pronunciation, but helped to resolve homophonic ambiguities.

The three most important systems of ancient writing were developed in Egypt, in Sumer at the mouth of the Tigris and Euphrates Rivers, and in China. Any connection between the three systems must have been prehistoric, because there are significant divergences even in their earliest pictographic stages.

Although there are a number of pictograms which are similar in all three systems of writing, these pictograms portray objects which ought to appear the same to all writers. Examples of objects with common appearances include sun, fire, water, fish, bird, and ox. In other cases, the Egyptian and Chinese representations show more similarity to each other than they do to the Sumerian representations. This divergence in appearance applies especially to the pictograms for man, woman, and child. When the pictograms have a more abstract interpretation, there is no apparent relationship at all. Thus the symbols for life do not seem to have any common relationship.

The ancient Egyptian system of writing began with the hieroglyphs or sacred carvings, which were used from 3100 B.C. to A.D. 394. A cursive form of hieroglyphic was hieratic or sacred writing, which was used from 2345 B.C. to A.D. 200. A cursive form of hieratic was demotic or popular writing, which was used from 650 B.C. to A.D. 470.

Hieroglyphic was written from left to right or from right to left according to esthetic considerations. The characters in the line of writing faced either way as necessary so that they always faced the beginning of the line. Hieratic and demotic normally were written from right to left. Hieroglyphs were highly calligraphic. Only a few lines were used deftly to indicate precisely the salient features of an object.

The ancient Sumerian system of writing was in use from 3100 B.C. until it fell into disuse around 300 B.C. and finally was used for the last time in 6 B.C. The earliest records were pictograms without systematic arrangement. When the pictograms began to be written from left to right they were turned on their sides with the tops oriented toward the left. Recording was by the impression of a stylus in a clay tablet. The pictograms evolved into highly stylized cuneiform characters with little resemblance to their pictorial origin. The Eastern Semites of Akkad adopted the cuneiform writing of the Sumerians. At one time the range of cuneiform writing extended from as far west as Ugarit on the Mediterranean to as far east as Persepolis in Persia.

The ancient Chinese system of writing goes back to the Shang dynasty which began in 1766 B.C. Many of the characters have retained much of their original pictographic structure. The earliest records were written with a writing stick. The ancient or *tensho* characters prevailed until after 200 B.C. The style of writing was revolutionized when the writing brush was invented about 800 B.C. The cursive or *sosho* characters have continued to modern times. The style of character was standardized by the calligrapher

Wang Hsi-Chih in about A.D. 400. The modern or *kaisho* style of character has been preserved since A.D. 600 by block printing.

The Egyptian hieroglyphs and the Chinese characters for a few basic concepts are compared in Figure 1. Included in the figure are those cuneiforms whose pictographic origins come the closest to equivalence with the hieroglyphs (son for child, plant for flower, copper for metal).

Phonographic Stage

The second stage of evolution was phonographic. Only enough symbols were retained as was necessary to achieve a phonetic representation. The original phonetic value of each symbol was retained as the name of the symbol, while the phonetic value of the symbol was contracted to a syllable with a single consonant. The vowels which were used with each consonant were a matter of tradition or convention and were not otherwise defined. The phonetic syllabary was developed by the Western Semites, who were influenced by Egypt in the West and by Akkad in the East. The Semitic syllabary does not seem to have appeared much before Moses or about 1250 B.C. The syllabary was used by the Phoenicians, the Arameans, and even the Assyrians. Evolution of the Aramaic syllabary led ultimately after 500 B.C. to the Hebrew syllabary and after A.D. 300 to the Arabic syllabary.

Chinese calligraphy was introduced into Japan at about A.D. 300 along with Confucianism and was introduced again in A.D. 507 along with Buddhism. It was not until A.D. 800 that the Chinese system of writing could be utilized effectively for writing Japanese. Parts of Chinese characters were extracted to form phonetic syllabaries. The *katakana* syllabary was invented by Kibi no Makibi and the *hiragana* syllabary was invented by Kobo Daishi. The *kanji* or Chinese characters still are used for the stems of words while the *kana* or phonetic characters are used for the inflections of words.

Alphabetic Stage

The third stage of evolution was alphabetic. The Greeks adopted those symbols from the Semites which were useful as consonants in Greek, and adapted other symbols to form a set of vowels. The Greeks took the names of the letters from the Semites. The Latins borrowed an early version of the alphabet from the Greeks. With a few minor additions the Latin alphabet became the Roman alphabet of today. It still is not truly phonetic insofar as many letters have a multiplicity of phonetic values. Thus there are seven different pronunciations of *A* in English, and the choice of pronunciation is a matter of convention.

Early Christian missionaries spread the alphabet to various countries. Thus Coptic was an Egyptian alphabet which contained Greek with seven symbols from demotic. Cyrillic is a modification of Greek which was brought to the Slavs by Cyril about A.D. 850. On the other hand, the Islamic conquerors have spread Arabic over a large part of the world since A.D. 640.

In early Christian times there was a great deal of activity in scriptoria where books were being copied. In the hurry of writing, some letters were rounded to become the uncial or inch-high style of writing in both Greek and Latin. The uncial style became the forerunner of the minuscule alphabets while the older style remained to become the majuscule alphabets. The ultimate of curvilinear writing were the script minuscules and the Lombardic majuscules of the Middle Ages. Artistic motivations led to the design of ornamental alphabets such as the Gothic alphabets which were used in illuminated manuscripts.

The invention of the printing press in A.D. 1454 has stimulated a great expansion in the design of new alphabets with the Roman, Italic, Greek, and Cyrillic alphabets as the prototypes. The minuscules became the lower case and the majuscules became the upper case of the printing press.

The one letter for which there is a phonetic counterpart in all writing systems is the letter A. The various versions of the letter A are illustrated in Figure 2. In Egyptian the hieroglyphic for eagle was used with its variants in hieratic and demotic to transliterate the A sound in foreign names such as *Kleopatra*. The cuneiform for water was used in Sumerian. Although the first symbol of the Semitic syllabary is not equivalent to the letter A, it is the forerunner of the first letter of the alphabet. It was derived originally from a pictogram for the face of an ox. In Akkadian the pictogram was turned with the horns pointing toward the left, in Phoenician the pictogram was turned with the horns pointing toward the right, while when the Greeks adopted it, they turned the pictogram completely upside down.

Numerals

The earliest representations of numerals were sets of marks such that the number of marks was equal to the value of the numeral for small numerals with special marks for ten. The Babylonians had special cuneiforms also for 60 and 600 while the Egyptians had special hieroglyphs for 100 and 1000. The Egyptians used arbitrary symbols to represent each of the smallest numerals in hieratic and demotic. At first the Greeks used Π for *pente* or 5, Δ for *deka* or 10, Η for *hekatōn* or 100, and Χ for *chilioi* or 1000, but after 200 B.C. they used the letters of the alphabet in serial order for the first few numerals. At the same time the Semites began to use the Hebrew syllabary for numerals. The Latins borrowed the early Greek system in principle but used arbitrarily those Greek letters which were not required for the Latin alphabet. Thus X was adopted for ten, Θ for hundred, and ϕ for thousand. The symbols were cut in half to give signs for five, fifty, and five hundred. The final result in Roman numerals was V for 5, X for 10, L for 50, C for 100, D for 500, and M for 1000.

From the earliest times the Chinese have had arbitrary signs for the smallest numerals with special signs for powers of ten.

Although the Babylonians had a mark to indicate an omission they did not have a true zero. The Mayans had a vigesimal number system with a zero sign. They had an accurate chronology which can be extrapolated back to an origin in 3114 B.C. The earliest date on record in the Mayan calendar is A.D. 292. The systematic use of zero sign and place value did not begin in India until after A.D. 650. The concept of zero was introduced into Europe by the Arabs through Spain in A.D. 976.

The various symbols for numerals from zero to ten are compared in Figure 3.

Conclusion

The latest quotation as to the origin of writing is 3100 B.C. The introduction of new systems of writing has accompanied the introduction of new systems of religion. Once a system of writing has become established, it tends to persist long after the annihilation of the system of politics under which it first appeared.

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LOGOGRAMS

HIEROGLYPHIC	CUNEIFORM	TENSHO	SOSHO	KAISHO	SIGNIFICANCE
☉	𐎗	日	日	日	sun, day
♀	𐎗𐎕	主	主	生	life
𐎗	𐎗	天	𐎗	天	heaven
𐎗	𐎗	土	𐎗	土	earth
𐎗	𐎗	山	𐎗	山	mountain
𐎗	𐎗	川	𐎗	川	river
𐎗	𐎗	火	𐎗	火	fire
𐎗	𐎗	水	𐎗	水	water
𐎗	𐎗	風	𐎗	風	wind
𐎗	𐎗	雨	𐎗	雨	rain
𐎗	𐎗	石	𐎗	石	stone
𐎗	𐎗	金	𐎗	金	metal
𐎗	𐎗	糸	𐎗	糸	thread
𐎗	𐎗	刀	𐎗	刀	sword
𐎗	𐎗	花	𐎗	花	flower
𐎗	𐎗	木	𐎗	木	tree
𐎗	𐎗	魚	𐎗	魚	fish
𐎗	𐎗	鳥	𐎗	鳥	bird
𐎗	𐎗	人	𐎗	人	man
𐎗	𐎗	女子	𐎗	女子	woman
𐎗	𐎗	子	𐎗	子	child
𐎗	𐎗	口	𐎗	口	mouth
𐎗	𐎗	目	𐎗	目	eye
𐎗	𐎗	手	𐎗	手	hand
𐎗	𐎗	足	𐎗	足	foot
𐎗	𐎗	肉	𐎗	肉	flesh
𐎗	𐎗	心	𐎗	心	heart

Figure 1

PHONOGRAMS

- A -

HIEROGLYPHIC 𐦎 (eagle)	SUMERIAN 𒀭 (water)	GREEK Α, α
HIERATIC Ⲁ	AKKADIAN 𒀭 (ox)	CYRILLIC А, а
DEMOTIC Ⲁ	PHOENICIAN 𐤀	LOMBARDIC 𐌂, a
TENSHO 𐤀	HEBREW א	GERMAN 𐌂, a
SOSHO 𐤀	ARABIC ا	ENGLISH A, a
KAISHO 𐤀	GREEK Α	ROMAN A, a
HIRAGANA あ	LATIN A	ITALIC A, a
KATAKANA ア	UNCIAL λ	SCRIPT A, a

Figure 2

NUMERALS

HIEROGLYPHIC	HIERATIC	DEMOTIC	CUNEIFORM	GREEK	LATIN	TENSHO	SOSHC	KAISHO	MAYAN	HINDU-ARABIC	GOTHIC
I	I	I	I	I	I	I	I	一	•	0	0
II	4	4	II	II	II	II	2	二	:	1	1
III	III	6	III	III	III	III	3	三	:	2	2
IIII	4	5	II	IIII	IV	四	4	四	...	3	3
IIII	7	7	W	II	V	五	5	五	—	4	4
IIII	2	2	III	II	VI	六	6	六	—	5	5
IIII	2	4	W	IIII	VII	七	7	七	—	6	6
IIII	3	2	III	IIII	VIII	八	8	八	—	7	7
IIII	4	7	III	IIII	IX	九	9	九	—	8	8
0	^	λ	<	Δ	X	+	+	十	=	9	9

Figure 3

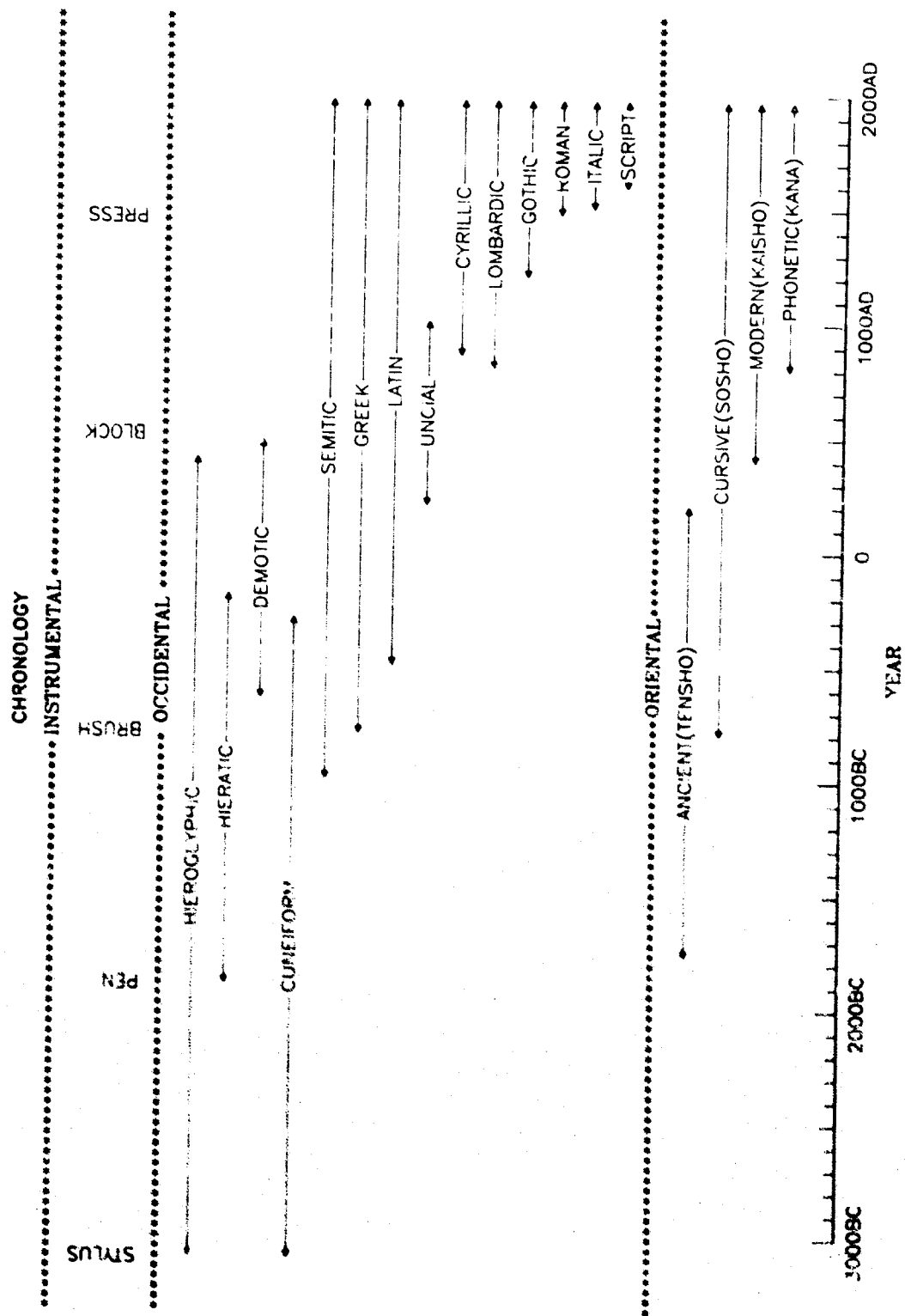


Figure 4

APPENDIX F

LEXICON

ROMAN	ROMAN	ITALIC	ITALIC
size	SIZE	<i>size</i>	<i>SIZE</i>
style	STYLE	<i>style</i>	<i>STYLE</i>
symbol	SYMBOL	<i>symbol</i>	<i>SYMBOL</i>
calligraphy	CALLIGRAPHY	<i>calligraphy</i>	<i>CALLIGRAPHY</i>
cartography	CARTOGRAPHY	<i>cartography</i>	<i>CARTOGRAPHY</i>
typography	TYPOGRAPHY	<i>typography</i>	<i>TYPOGRAPHY</i>
establishment	ESTABLISHMENT	<i>establishment</i>	<i>ESTABLISHMENT</i>
manufacture	MANUFACTURE	<i>manufacture</i>	<i>MANUFACTURE</i>
advertisement	ADVERTISEMENT	<i>advertisement</i>	<i>ADVERTISEMENT</i>
explanation	EXPLANATION	<i>explanation</i>	<i>EXPLANATION</i>
knowledge	KNOWLEDGE	<i>knowledge</i>	<i>KNOWLEDGE</i>
analysis	ANALYSIS	<i>analysis</i>	<i>ANALYSIS</i>
synthesis	SYNTHESIS	<i>synthesis</i>	<i>SYNTHESIS</i>
judgment	JUDGMENT	<i>judgment</i>	<i>JUDGMENT</i>
inspiration	INSPIRATION	<i>inspiration</i>	<i>INSPIRATION</i>
qualification	QUALIFICATION	<i>qualification</i>	<i>QUALIFICATION</i>
art	ART	<i>art</i>	<i>ART</i>
science	SCIENCE	<i>science</i>	<i>SCIENCE</i>
music	MUSIC	<i>music</i>	<i>MUSIC</i>
mechanics	MECHANICS	<i>mechanics</i>	<i>MECHANICS</i>
electronics	ELECTRONICS	<i>electronics</i>	<i>ELECTRONICS</i>
chemistry	CHEMISTRY	<i>chemistry</i>	<i>CHEMISTRY</i>
mathematics	MATHEMATICS	<i>mathematics</i>	<i>MATHEMATICS</i>
philosophy	PHILOSOPHY	<i>philosophy</i>	<i>PHILOSOPHY</i>
orthodoxy	ORTHODOXY	<i>orthodoxy</i>	<i>ORTHODOXY</i>

ROMAN	ROMAN	SCRIPT	SCRIPT
size	SIZE	<i>size</i>	<i>JSSE</i>
style	STYLE	<i>style</i>	<i>JSYL</i>
symbol	SYMBOL	<i>symbol</i>	<i>SYMBOL</i>
calligraphy	CALLIGRAPHY	<i>calligraphy</i>	<i>CALLIGRAPHY</i>
cartography	CARTOGRAPHY	<i>cartography</i>	<i>CARTOGRAPHY</i>
typography	TYPOGRAPHY	<i>typography</i>	<i>TYPOGRAPHY</i>
establishment	ESTABLISHMENT	<i>establishment</i>	<i>ESTABLISHMENT</i>
manufacture	MANUFACTURE	<i>manufacture</i>	<i>MANUFACTURE</i>
advertisement	ADVERTISEMENT	<i>advertisement</i>	<i>ADVERTISEMENT</i>
explanation	EXPLANATION	<i>explanation</i>	<i>EXPLANATION</i>
knowledge	KNOWLEDGE	<i>knowledge</i>	<i>KNOWLEDGE</i>
analysis	ANALYSIS	<i>analysis</i>	<i>ANALYSIS</i>
synthesis	SYNTHESIS	<i>synthesis</i>	<i>SYNTHESIS</i>
judgment	JUDGMENT	<i>judgment</i>	<i>JUDGMENT</i>
inspiration	INSPIRATION	<i>inspiration</i>	<i>INSPIRATION</i>
qualification	QUALIFICATION	<i>qualification</i>	<i>QUALIFICATION</i>
art	ART	<i>art</i>	<i>ART</i>
science	SCIENCE	<i>science</i>	<i>SCIENCE</i>
music	MUSIC	<i>music</i>	<i>MUSIC</i>
mechanics	MECHANICS	<i>mechanics</i>	<i>MECHANICS</i>
electronics	ELECTRONICS	<i>electronics</i>	<i>ELECTRONICS</i>
chemistry	CHEMISTRY	<i>chemistry</i>	<i>CHEMISTRY</i>
mathematics	MATHEMATICS	<i>mathematics</i>	<i>MATHEMATICS</i>
philosophy	PHILOSOPHY	<i>philosophy</i>	<i>PHILOSOPHY</i>
orthodoxy	ORTHODOXY	<i>orthodoxy</i>	<i>ORTHODOXY</i>

ENGLISH	ENGLISH	LOMBARDIC	LOMBARDIC
size	SIZE	size	SIZE
style	STYLE	style	STYLE
symbol	SYMBOL	symbol	SYMBOL
calligraphy	CALLIGRAPHY	calligraphy	CALLIGRAPHY
cartography	CARTOGRAPHY	cartography	CARTOGRAPHY
typography	TYPOGRAPHY	typography	TYPOGRAPHY
establishment	ESTABLISHMENT	establishment	ESTABLISHMENT
manufacture	MANUFACTURE	manufacture	MANUFACTURE
advertisement	ADVERTISEMENT	advertisement	ADVERTISEMENT
explanation	EXPLANATION	explanation	EXPLANATION
knowledge	KNOWLEDGE	knowledge	KNOWLEDGE
analysis	ANALYSIS	analysis	ANALYSIS
synthesis	SYNTHESIS	synthesis	SYNTHESIS
judgment	JUDGMENT	judgment	JUDGMENT
inspiration	INSPIRATION	inspiration	INSPIRATION
qualification	QUALIFICATION	qualification	QUALIFICATION
art	ART	art	ART
science	SCIENCE	science	SCIENCE
music	MUSIC	music	MUSIC
mechanics	MECHANICS	mechanics	MECHANICS
electronics	ELECTRONICS	electronics	ELECTRONICS
chemistry	CHEMISTRY	chemistry	CHEMISTRY
mathematics	MATHEMATICS	mathematics	MATHEMATICS
philosophy	PHILOSOPHY	philosophy	PHILOSOPHY
orthodoxy	ORTHODOXY	orthodoxy	ORTHODOXY

FRENCH	ENGLISH	FRENCH	ENGLISH
zéro	zero	fleur	flower
un	one	arbre	tree
deux	two	poisson	fish
trois	three	oiseau	bird
quatre	four	boeuf	ox
cinq	five	homme	man
six	six	femme	woman
sept	seven	enfant	child
huit	eight	bouche	mouth
neuf	nine	oeil	eye
dix	ten	main	hand
soleil	sun	pied	foot
vie	life	chair	flesh
ciel	heaven	coeur	heart
terre	earth	âme	soul
montagne	mountain	amour	love
rivière	river	loi	law
feu	fire	texte	text
eau	water	quantité	quantity
vent	wind	système	system
pluie	rain	mécanique	mechanics
pierre	stone	électronique	electronics
métal	metal	chimie	chemistry
fil	thread	mathématiques	mathematics
sabre	sword	philosophie	philosophy

FRENCH	ENGLISH
ZÉRO	zero
UN	one
DEUX	two
TROIS	three
QUATRE	four
CINQ	five
SIX	six
SEPT	seven
HUIT	eight
NEUF	nine
DIX	ten
SOLEIL	sun
VIE	life
CIEL	heaven
TERRE	earth
MONTAGNE	mountain
RIVIÈRE	river
FEU	fire
EAU	water
VENT	wind
PLUIE	rain
PIERRE	stone
MÉTAL	metal
FIL	thread
SABRE	sword

FRENCH	ENGLISH
FLEUR	flower
ARBRE	tree
POISSON	fish
OISEAU	bird
BOEUF	ox
HOMME	man
FEMME	woman
ENFANT	child
BOUCHE	mouth
OEIL	eye
MAIN	hand
PIED	foot
CHAIR	flesh
COEUR	heart
ÂME	soul
AMOUR	love
LOI	law
TEXTE	text
QUANTITÉ	quantity
SYSTÈME	system
MÉCANIQUE	mechanics
ÉLECTRONIQUE	electronics
CHIMIE	chemistry
MATHÉMATIQUES	mathematics
PHILOSOPHIE	philosophy

GERMAN	ENGLISH	GERMAN	ENGLISH
Null	zero	Blume	flower
Ein	one	Baum	tree
Zwei	two	Fisch	fish
Drei	three	Vogel	bird
Vier	four	Ochs	ox
Fünf	five	Mann	man
Sechs	six	Frau	woman
Sieben	seven	Kind	child
Acht	eight	Mund	mouth
Neun	nine	Auge	eye
Zehn	ten	Hand	hand
Sonne	sun	Fuß	foot
Leben	life	Fleisch	flesh
Himmel	heaven	Herz	heart
Erde	earth	Seele	soul
Berg	mountain	Liebe	love
Fluß	river	Gesetz	law
Feuer	fire	Text	text
Wasser	water	Quantität	quantity
Wind	wind	System	system
Regen	rain	Mechanik	mechanics
Stein	stone	Elektronik	electronics
Metall	metal	Chemie	chemistry
Nadel	thread	Mathematik	mathematics
Schwert	sword	Philosophie	philosophy

GERMAN	ENGLISH	GERMAN	ENGLISH
NULL	zero	BLUM	flower
ONE	one	BAUM	tree
ZWEI	two	FISCH	fish
DREI	three	VOGEL	bird
VIERT	four	OS	ox
FUNF	five	MANN	man
SECHS	six	FRAU	woman
SEBEN	seven	KIND	child
ACHT	eight	MUND	mouth
NEUN	nine	AUGE	eye
ZEHN	ten	HAND	hand
SUNNE	sun	FUSS	foot
LEBEN	life	FLEISCH	flesh
HIMMEL	heaven	HERZ	heart
ERDE	earth	SEELE	soul
BERG	mountain	VERE	love
FLUSS	river	GESETZ	law
FEUER	fire	TEXT	text
WASSER	water	ANZAHL	quantity
WIND	wind	SYSTEM	system
REGEN	rain	MECHANIK	mechanics
STEIN	stone	ELEKTRONIK	electronics
METALL	metal	CHEMIE	chemistry
ADLER	thread	MATHEMATIK	mathematics
SCHWERT	sword	PHILOSOPHIE	philosophy

GREEK	ENGLISH	GREEK	ENGLISH
μηδέν	zero	άνθος	flower
εἷς	one	δένδρον	tree
δύο	two	ιχθύς	fish
τρεῖς	three	πτηνόν	bird
τέσσαρες	four	βοῦς	ox
πέντε	five	άνθρωπος	man
ἕξ	six	γυνή	woman
ἐπτά	seven	παιδίον	child
ὀκτώ	eight	στόμα	mouth
ἐννέα	nine	ὀφθαλμός	eye
δέκα	ten	χεῖρ	hand
ἥλιος	sun	πόδι	foot
ζωή	life	σάρξ	flesh
οὐρανός	heaven	καρδία	heart
γῆ	earth	ψυχή	soul
ὄρος	mountain	ἔρως	love
ποταμός	river	νόμος	law
πῦρ	fire	θέμα	text
ὕδωρ	water	ποσότης	quantity
άνεμος	wind	σύστημα	system
βροχή	rain	μηχανική	mechanics
λίθος	stone	ἠλεκτρονική	electronics
μέταλλον	metal	χημεία	chemistry
νῆμα	thread	μαθηματικά	mathematics
ξίφος	sword	φιλοσοφία	philosophy

GREEK	ENGLISH
ΜΗΔΕΝ	zero
ΕΙΣ	one
ΔΥΟ	two
ΤΡΕΙΣ	three
ΤΕΣΣΑΡΕΣ	four
ΠΕΝΤΕ	five
ΕΞ	six
ΕΠΤΑ	seven
ΟΚΤΩ	eight
ΕΝΝΕΑ	nine
ΔΕΚΑ	ten
ΗΛΙΟΣ	sun
ΖΩΗ	life
ΟΥΡΑΝΟΣ	heaven
ΓΗ	earth
ΟΡΟΣ	mountain
ΠΟΤΑΜΟΣ	river
ΠΥΡ	fire
ΥΔΩΡ	water
ΑΝΕΜΟΣ	wind
ΒΡΟΧΗ	rain
ΛΙΘΟΣ	stone
ΜΕΤΑΛΛΟΝ	metal
ΝΗΜΑ	thread
ΞΙΦΟΣ	sword

GREEK	ENGLISH
ΑΝΘΟΣ	'lower
ΔΕΝΔΡΟΝ	tree
ΙΧΘΥΣ	fish
ΠΤΗΝΟΝ	bird
ΒΟΥΣ	ox
ΑΝΘΡΩΠΟΣ	man
ΓΥΝΗ	woman
ΠΑΙΔΙΟΝ	child
ΣΤΟΜΑ	mouth
ΟΦΘΑΛΜΟΣ	eye
ΧΕΙΡ	hand
ΠΟΔΙ	foot
ΣΑΡΞ	flesh
ΚΑΡΔΙΑ	heart
ΨΥΧΗ	soul
ΕΡΩΣ	love
ΝΟΜΟΣ	law
ΘΕΜΑ	text
ΠΟΣΟΤΗΣ	quantity
ΣΥΣΤΗΜΑ	system
ΜΗΧΑΝΙΚΗ	mechanics
ΗΛΕΚΤΡΟΝΙΚΗ	electronics
ΧΗΜΕΙΑ	chemistry
ΜΑΘΗΜΑΤΙΚΑ	mathematics
ΦΙΛΟΣΟΦΙΑ	philosophy

RUSSIAN	ENGLISH	RUSSIAN	ENGLISH
нуль	zero	цветок	flower
один	one	дерево	tree
два	two	рыба	fish
три	three	птица	bird
четыре	four	бык	ox
пять	five	человек	man
шесть	six	женщина	woman
семь	seven	ребенок	child
восемь	eight	уста	mouth
девять	nine	око	eye
десять	ten	рука	hand
солнце	sun	нога	foot
жизнь	life	мясо	flesh
небо	heaven	сердце	heart
земля	earth	душа	soul
гора	mountain	любовь	love
река	river	закон	law
огонь	fire	текст	text
вода	water	количество	quantity
ветер	wind	система	system
дождь	rain	механика	mechanics
камень	stone	электроника	electronics
металл	metal	химия	chemistry
нитка	thread	математика	mathematics
меч	sword	философия	philosophy

RUSSIAN	ENGLISH	RUSSIAN	ENGLISH
НУЛЬ	zero	ЦВЕТOK	flower
ОДИН	one	ДЕРЕВО	tree
ДВА	two	РЫБА	fish
ТРИ	three	ПТИЦА	bird
ЧЕТЫРЕ	four	БЫК	ox
ПЯТЬ	five	ЧЕЛОВЕК	man
ШЕСТЬ	six	ЖЕНЩИНА	woman
СЕМЬ	seven	РЕБЕНОК	child
ВОСЕМЬ	eight	УСТА	mouth
ДЕВЯТЬ	nine	ОКО	eye
ДЕСЯТЬ	ten	РУКА	hand
СОЛНЦЕ	sun	НОГА	foot
ЖИЗНЬ	life	МЯСО	flesh
НЕБО	heaven	СЕРДЦЕ	heart
ЗЕМЛЯ	earth	ДУША	soul
ГОРА	mountain	ЛЮБОВЬ	love
РЕКА	river	ЗАКОН	law
ОГОНЬ	fire	ТЕКСТ	text
ВОДА	water	КОЛИЧЕСТВО	quantity
ВЕТЕР	wind	СИСТЕМА	system
ДОЖДЬ	rain	МЕХАНИКА	mechanics
КАМЕНЬ	stone	ЭЛЕКТРОНИКА	electronics
МЕТАЛЛ	metal	ХИМИЯ	chemistry
НИТКА	thread	МАТЕМАТИКА	mathematics
МЕЧ	sword	ФИЛОСОФИЯ	philosophy

APPENDIX G

PATTERNS

Invitation

COMMUNICATION

Publication

ECONOMY

VERSATILITY

Quality

CARTOGRAPHY

Standardization

TYPOGRAPHY

Γραμμα

Συμβολον

Αριθμος

Графика

СЛОЖНОСТЬ

Фонетика

Rotation

EXTENSION

ROTATION

CONDENSATION

Inclination

ΛΕΞΙΚΟΝ

INCLINATION

Art

書道

Music

Meteorology

Wissenschaft

Astronomy

CHEMISTRY

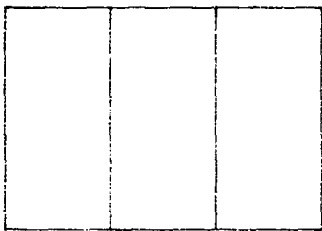
Electronics

MATHEMATICS

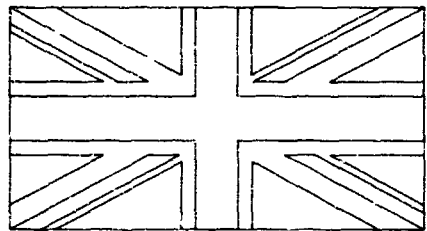
LINCOLN'S GETTYSBURG ADDRESS

Fourscore and seven years ago our fathers brought forth on this continent a new nation conceived in liberty and dedicated to the proposition that all men are created equal. Now we are engaged in a great civil war testing whether that nation, or any nation so conceived and so dedicated, can long endure. We are met on a great battlefield of that war. We have come to dedicate a portion of that field as a final resting-place for those who here gave their lives that that nation might live. It is altogether fitting and proper that we should do this. But, in a larger sense, we cannot dedicate, we cannot consecrate, we cannot hallow this ground. The brave men, living and dead, who struggled here have consecrated it far above our poor power to add or detract. The world will little note nor long remember what we say here, but it can never forget what they did here. It is for us the living rather to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced. It is rather for us to be here dedicated to the great task remaining before us—that from these honored dead we take increased devotion to that cause for which they gave the last full measure of devotion—that we here highly resolve that these dead shall not have died in vain, that this nation under God shall have a new birth of freedom, and that government of the people, by the people, for the people shall not perish from the earth.

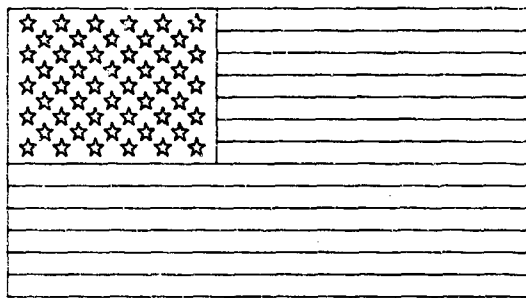
FLAGS



FRANCE



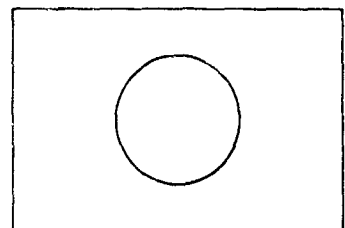
UNITED KINGDOM



UNITED STATES



CHINA



JAPAN

SYMBOLS

*	/	%	&	@	\$	#	§	†	‡
∞	≡	S	,	.	*	△	≈	▽	R
T	-	~	⤿	◁	↪	↗	↘	→	*~
♂	♀	☼	Ω	♋	♎	♏	♐	♑	♒
◎	♀	♀	⊕	♂	♈	♉	♊	♋	P
☆	✦	©	♣	♠	🔔	♣	♥	♦	♣
●	■	▲	★	+	x	*	①	②	③
○	□	△	☆	▧	◇	◆	◇	◇	◆
×	Λ	風	古	止	灬	†	丰	花	心
旗	十	⊙	⊙	★	Ⓡ	↑	(206)	(301)	(95)

MUSIC

TONES



C C#, Db D D#, Eb E F F#, Gb G G#, Ab A A#, Bb B C

SIGNATURES



C, a G, e D, b A, f# E, c# B, g# F#, d# C#, a#

SIGNATURES



C, a F, d Bb, g Eb, c Ab, f Db, bb Cb, fb Cb, ab

NOTATION
















































Notes and Rests

Triads

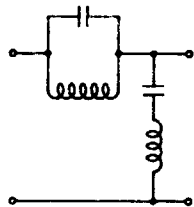
Slurs and Beams

ELECTRONICS

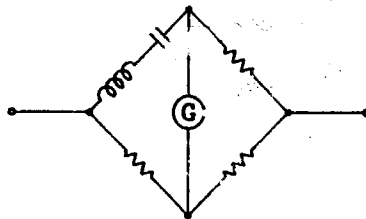
FIXED RESISTOR	FUSE	BATTERY	VACUUM DIODE	P-N DIODE
				
FIXED CAPACITOR	SPARK GAP	THERMOCOUPLE	VACUUM TRIODE	TUNNEL DIODE
				
FIXED INDUCTOR	SELECTOR SWITCH	ANTENNA, GROUND	VACUUM TETRODE	TRIAC SWITCH
				
VARIABLE RESISTOR	HEATER	TRANSFORMER	VACUUM PENTODE	UNIUNCTION TRANSISTOR
				
VARIABLE CAPACITOR	LOUDSPEAKER	MICROPHONE	TWIN TRIODE	N-P-N TRANSISTOR
				
VARIABLE INDUCTOR	CRYSTAL	COAXIAL CABLE	MAGNETRON	P-N-P TRANSISTOR
				
POTENTIOMETER	LAMP	AF MATURE	VACUUM PHOTOTUBE	COLD CATHODE TUBE
				
SPLIT-STATOR CAPACITOR	GALVANOMETER	ALTERNATOR	MULTIPLIER PHOTOTUBE	THYRATRON
				
AUTOTRANSFORMER	ELECTROMETER	SYNCHRO	CATHODE-RAY TUBE	IGNITRON
				

NETWORKS

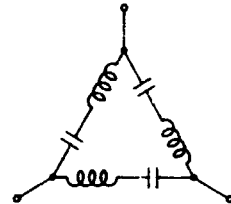
BAND-STOP FILTER



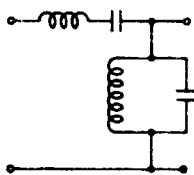
FREQUENCY BRIDGE



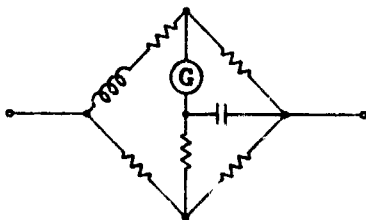
Δ -CONNECTION



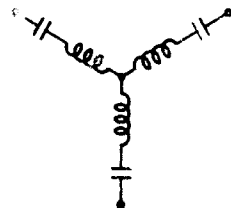
BAND-PASS FILTER



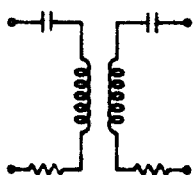
ANDERSON'S BRIDGE



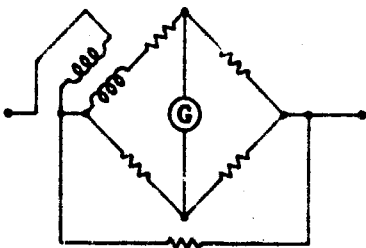
Y-CONNECTION



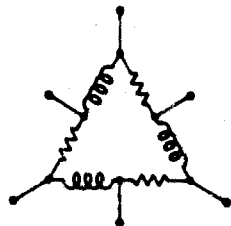
INDUCTIVE COUPLING



MAXWELL'S BRIDGE

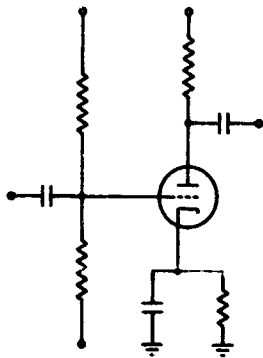


PHASE CONVERTER

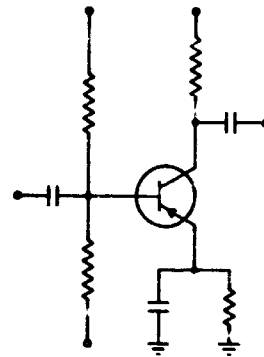


AMPLIFIERS

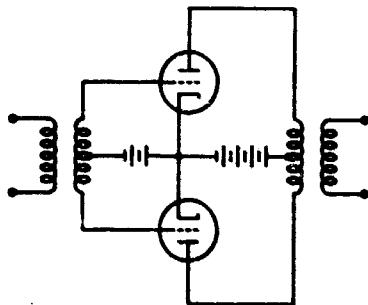
CLASS A AMPLIFIER



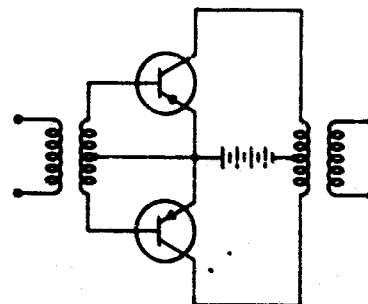
CLASS A AMPLIFIER



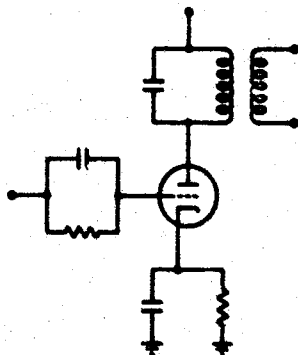
CLASS B AMPLIFIER



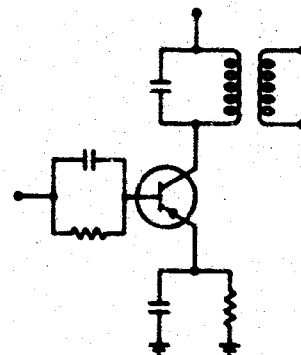
CLASS B AMPLIFIER



CLASS C AMPLIFIER

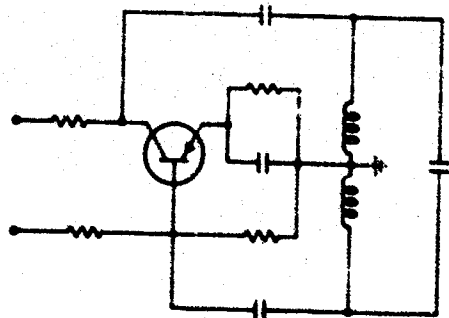


CLASS C AMPLIFIER

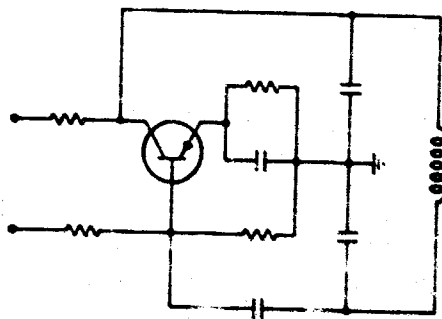


OSCILLATORS

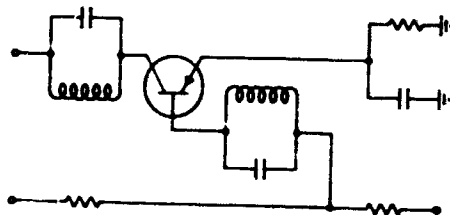
HARTLEY OSCILLATOR



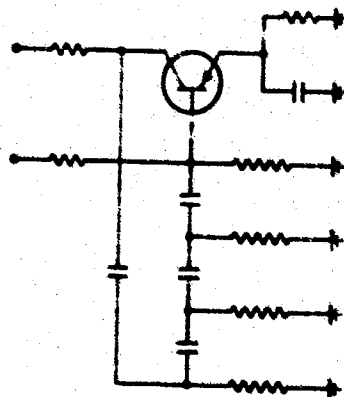
COLPITTS OSCILLATOR



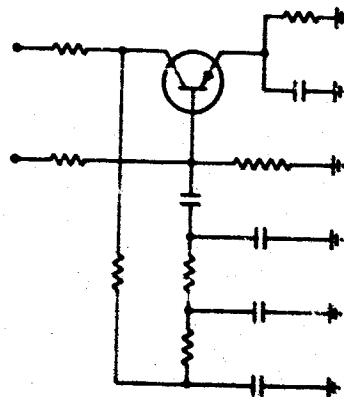
TUNED-GRID-TUNED-PLATE OSCILLATOR



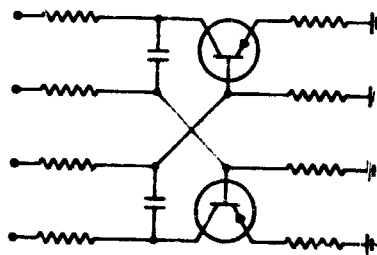
PHASE-SHIFT OSCILLATOR



PHASE-SHIFT OSCILLATOR

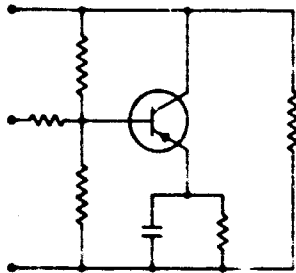


SQUARE-WAVE OSCILLATOR



MODULATORS AND DETECTORS

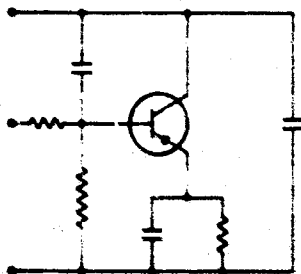
RESISTANCE MODULATOR



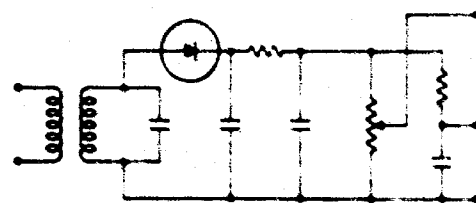
RECTIFIER



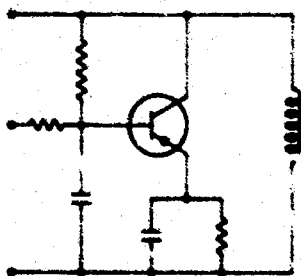
CAPACITANCE MODULATOR



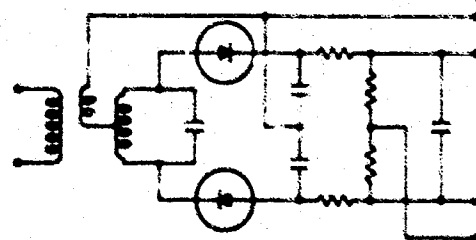
AMPLITUDE DETECTOR



INDUCTANCE MODULATOR

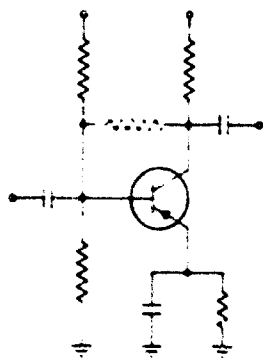


RATIO DETECTOR

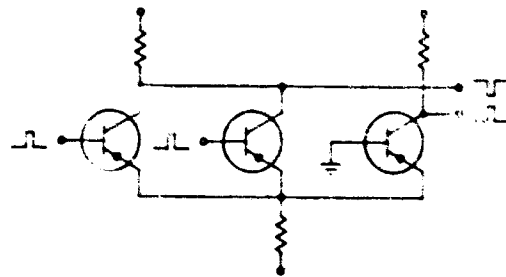


COMPUTER COMPONENTS

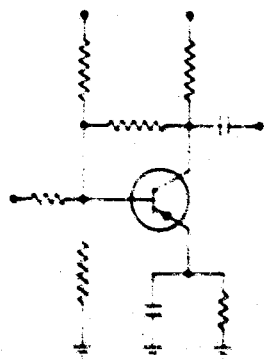
DIFFERENTIATOR



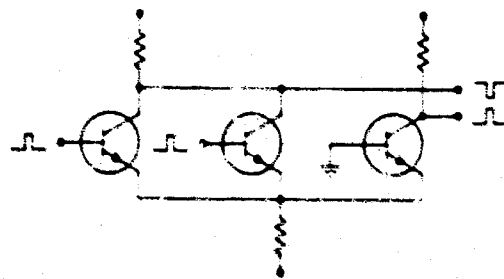
AND GATE



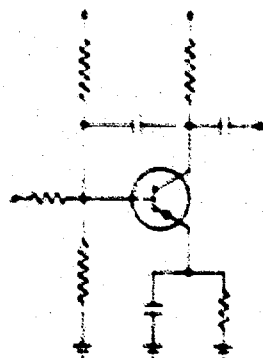
INVERTER



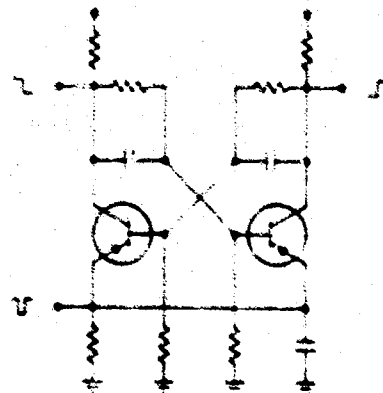
OR GATE



INTEGRATOR

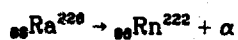


BISTABLE MULTIVIBRATOR

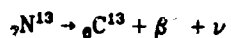
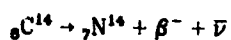


RADIOACTIVITY

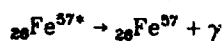
ALPHA DECAY



BETA DECAY



GAMMA DECAY



RADIOACTIVE SERIES

Thorium



Neptunium



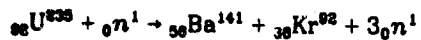
Uranium



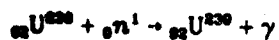
Actinium



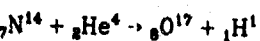
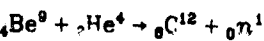
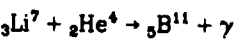
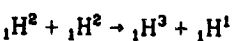
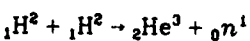
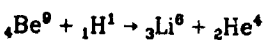
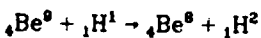
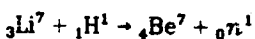
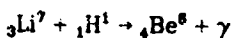
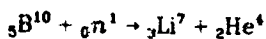
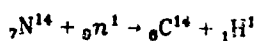
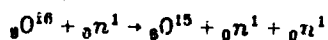
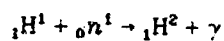
FISSION



FUSION



NUCLEAR REACTIONS



ELEMENTARY PARTICLES

MUON DECAY

$$\mu^- \rightarrow e^- + \nu + \bar{\nu}$$

$$\mu^+ \rightarrow e^+ + \nu + \bar{\nu}$$

PION DECAY

$$\pi^- \rightarrow \mu^- + \bar{\nu}$$

$$\pi^0 \rightarrow \gamma + \gamma$$

$$\pi^+ \rightarrow \mu^+ + \nu$$

KAON DECAY

$$K^- \rightarrow \pi^- + \pi^0$$

$$K^- \rightarrow \pi^- + \pi^0 + \pi^0$$

$$K^- \rightarrow \pi^- + \pi^+ + \pi^-$$

$$K^- \rightarrow \mu^- + \bar{\nu}$$

$$K^- \rightarrow \mu^- + \pi^0 + \bar{\nu}$$

$$K^- \rightarrow e^- + \pi^0 + \bar{\nu}$$

$$K^0, \bar{K}^0 \rightarrow \pi^0 + \pi^0$$

$$K^0, \bar{K}^0 \rightarrow \pi^- + \pi^+$$

$$K^0, \bar{K}^0 \rightarrow \pi^0 + \pi^0 + \pi^0$$

$$K^0, \bar{K}^0 \rightarrow \pi^0 + \pi^- + \pi^+$$

$$K^0, \bar{K}^0 \rightarrow \mu^- + \pi^+ + \bar{\nu}$$

$$K^0, \bar{K}^0 \rightarrow \mu^+ + \pi^- + \nu$$

$$K^0, \bar{K}^0 \rightarrow e^- + \pi^+ + \bar{\nu}$$

$$K^0, \bar{K}^0 \rightarrow e^+ + \pi^- + \nu$$

$$K^+ \rightarrow \pi^+ + \pi^0$$

$$K^+ \rightarrow \pi^+ + \pi^0 + \pi^0$$

$$K^+ \rightarrow \pi^+ + \pi^- + \pi^+$$

$$K^+ \rightarrow \mu^+ + \nu$$

$$K^+ \rightarrow \mu^+ + \pi^0 + \nu$$

$$K^+ \rightarrow e^+ + \pi^0 + \nu$$

NUCLEON DECAY

$$n \rightarrow p + \beta^- + \bar{\nu}$$

$$p \rightarrow n + \beta^+ + \nu$$

HYPERON DECAY

$$\Lambda^0 \rightarrow n + \pi^0$$

$$\Lambda^0 \rightarrow p + \pi^-$$

$$\Sigma^- \rightarrow n + \pi^-$$

$$\Sigma^0 \rightarrow \Lambda^0 + \gamma$$

$$\Sigma^+ \rightarrow n + \pi^+$$

$$\Sigma^+ \rightarrow p + \pi^0$$

$$\Xi^- \rightarrow \Lambda^0 + \pi^-$$

$$\Xi^0 \rightarrow \Lambda^0 + \pi^0$$

PION PRODUCTION

$$n + \gamma \rightarrow p + \pi^-$$

$$n + \gamma \rightarrow n + \pi^0$$

$$p + \gamma \rightarrow p + \pi^0$$

$$p + \gamma \rightarrow n + \pi^+$$

$$p + n \rightarrow p + p + \pi^-$$

$$p + n \rightarrow n + n + \pi^+$$

ELECTRON PAIR PRODUCTION

$$p + \gamma \rightarrow p + \beta^- + \beta^+$$

ELECTRON PAIR ANNIHILATION

$$e^- + e^+ \rightarrow \gamma + \gamma$$

PROTON PAIR PRODUCTION

$$p + \pi^- \rightarrow n + p + \bar{p}$$

$$p + p \rightarrow p + p + p + \bar{p}$$

PROTON PAIR ANNIHILATION

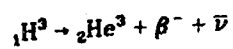
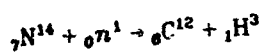
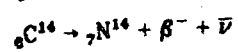
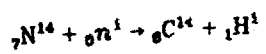
$$p + \bar{p} \rightarrow \pi^+ + \pi^+ + \pi^- + \pi^-$$

$$p + \bar{p} \rightarrow n + \bar{n}$$

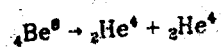
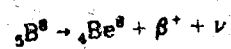
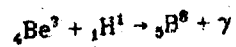
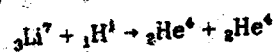
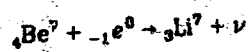
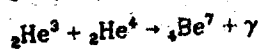
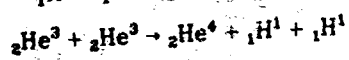
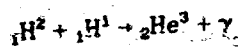
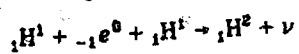
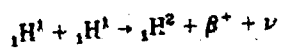
$$p + \bar{p} \rightarrow \Lambda^0 + \bar{\Lambda}^0$$

SOLAR REACTIONS

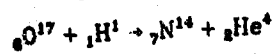
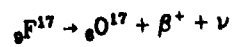
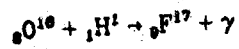
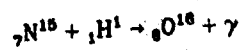
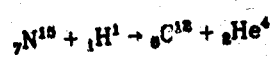
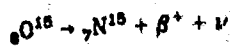
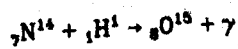
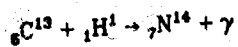
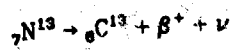
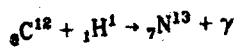
ATMOSPHERIC TRANSMUTATION



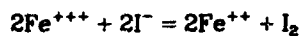
P-P CHAIN



CNO BICYCLE



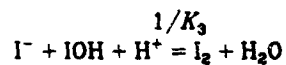
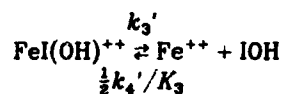
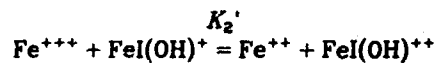
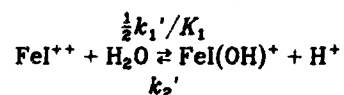
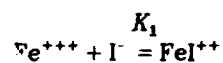
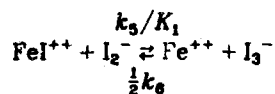
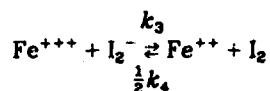
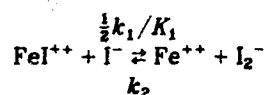
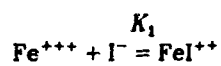
REACTION KINETICS



POTENTIALS



CHAINS



RATE LAW

$$\begin{aligned} \frac{d(\text{Fe}^{++})}{dt} = & \frac{k_1(\text{Fe}^{+++})(\text{I}^-)^2}{1 + \frac{(\text{Fe}^{++})/(\text{Fe}^{+++})}{\epsilon_4 + \epsilon_6(\text{I}^-)}} - \frac{k_4(\text{Fe}^{++})(\text{I}_2) + k_6(\text{Fe}^{++})(\text{I}_3^-)}{1 + \frac{\epsilon_4 + \epsilon_6(\text{I}^-)}{(\text{Fe}^{++})/(\text{Fe}^{+++})}} \\ & + \frac{k_1'(\text{Fe}^{+++})(\text{I}^-)}{1 + \frac{(\text{H}^+)(\text{Fe}^{++})}{\epsilon'(\text{Fe}^{+++})}} - \frac{k_4'(\text{Fe}^{++})(\text{I}_2)/(\text{H}^+)(\text{I}^-)}{1 + \frac{1}{(\text{H}^+)(\text{I}^-) \epsilon'(\text{Fe}^{+++})}} \end{aligned}$$

$$\epsilon_4 = k_3/k_2$$

$$\epsilon_6 = k_5/k_2$$

$$\epsilon' = K_2'k_3'/k_2'$$

REFERENCE: J.A.C.S., 55, 1760 (1933).

GROUPS

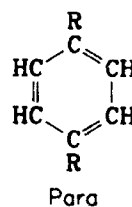
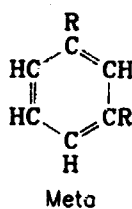
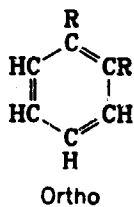
ISOELECTRONIC SEQUENCE

Neon	Hydrogen Fluoride	Water	Ammonia	Methane
Ne	HF	H ₂ O	NH ₃	CH ₄

RADICALS

Halo	-X	Hydroxyl	-OH	Amino	-NH ₂	Methyl	-CH ₃
		Oxy	>O	Imino	>NH	Methylene	>CH ₂
				Nitrilo	≡N	Methenyl	≡CH
				Isonitroso	>NOH	Carbonyl	>CO
				Nitroso	-NO	Cyano	-CN
				Nitro	-NO ₂	Carboxyl	-COOH

BENZENE RINGS



ALKYL HALIDE



ALCOHOL



ALKYL AMINE



ALKANE



PHENYL HALIDE



PHENOL



ANILINE



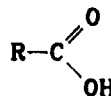
TOLUENE



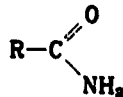
ACYL HALIDE



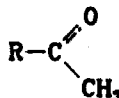
ACID



ACYL AMIDE



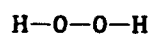
KETONE



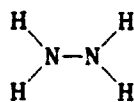
FLUORINE



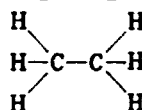
HYDROGEN PEROXIDE



HYDRAZINE



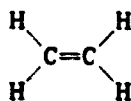
ETHANE



OXYGEN



ETHYLENE



NITROGEN



ACETYLENE

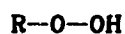


COMPOUNDS

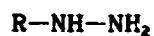
ALKYL HALIDE



ALKYL PEROXIDE



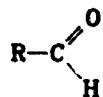
ALKYL HYDRAZINE



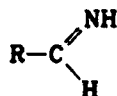
ALKANE



ALDEHYDE



ALKYL IMINE



ALKENE



ALKYL NITRILE



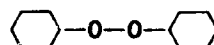
ALKYNE



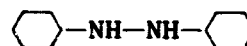
HALOGEN



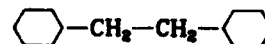
DIPHENYL PEROXIDE



HYDRAZOBENZENE



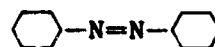
DIPHENYL ETHANE



OXYGEN



AZOBENZENE



DIPHENYL ETHYLENE



NITROGEN

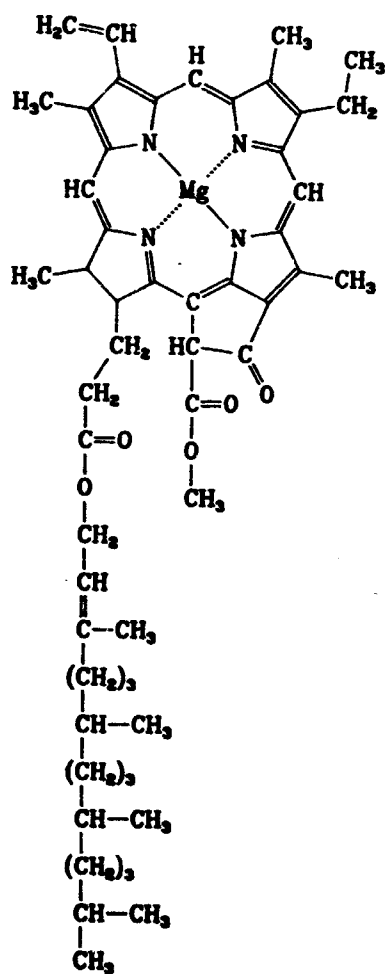


DIPHENYL ACETYLENE

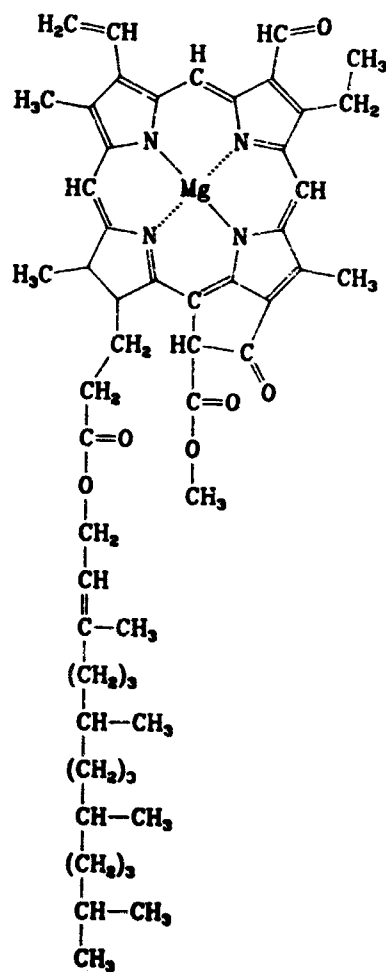


STRUCTURES

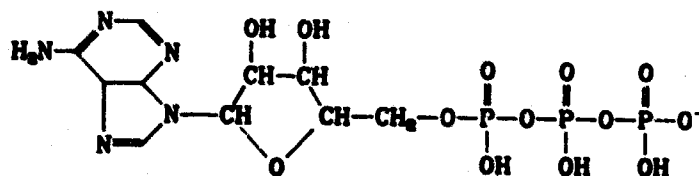
CHLOROPHYLL A



CHLOROPHYLL B



ADENOSINE TRIPHOSPHATE



MATHEMATICS

FRACTIONS

$$1/2$$

$$\frac{1}{2}$$

$$\frac{7}{15}$$

$$1/2$$

$$\frac{1}{2}$$

RADICALS

$$\sqrt{2}$$

$$\sqrt{2}$$

$$\frac{1}{\sqrt{\pi}}$$

$$\frac{\sqrt{2}}{2}$$

$$\sqrt{\frac{1}{2}}$$

ABBREVIATIONS

$$(\text{cm})/(\text{sec})$$

$$2\sin\theta\cos\theta$$

$$\tan^{-1}\frac{y}{x}$$

$$\cos^2\theta - \sin^2\theta$$

$$(\text{erg})/(\text{°})$$

EXPONENTS

$$x^{2n+1}$$

$$e^{i\omega t}$$

$$e^{-\frac{r^2}{4\Delta t}}$$

$$e^{-x^2}$$

$$x^{\frac{1}{2}}$$

SUMS

$$e^x = \sum_{n=0}^{\infty} \frac{x^n}{n!}$$

$$p(z) = \sum_{n=0}^N c_n z^n$$

$$p(z) = \prod_{n=1}^N (z - a_n)$$

$$\frac{\sin\theta}{\theta} = \prod_{n=1}^{\infty} \left(1 - \frac{\theta^2}{n^2\pi^2}\right)$$

PRODUCTS

FUNCTIONS

$$\Gamma(z)$$

$$J_n(z)$$

$$w(z)$$

$$P_n^m(z)$$

$$F(\phi, k)$$

DERIVATIVES

$$\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2} = 0$$

$$\frac{i\hbar\omega}{dz} = \frac{\partial u}{\partial x} - i \frac{\partial u}{\partial y} = \frac{\partial v}{\partial y} + i \frac{\partial v}{\partial x}$$

$$\left(\frac{\partial \varphi}{\partial x}\right)^2 + \left(\frac{\partial \varphi}{\partial y}\right)^2 = 1$$

INTEGRALS

$$\int_a^b f(x) dx$$

$$\int_0^1 f(z) dz$$

$$f(a) = \frac{1}{2\pi i} \oint \frac{f(z)}{z-a} dz$$

$$\int_a^b \frac{p(x)}{q(x)} dx$$

$$\int_a^b \frac{p(x)}{q(x)} dx$$

VECTORS

$$\mathbf{a} \cdot \mathbf{b} \times \mathbf{c} = \mathbf{a} \times \mathbf{b} \cdot \mathbf{c}$$

$$\int \mathbf{a} \cdot d\mathbf{s} = \int \nabla \cdot \mathbf{a} \, d\tau$$

$$\oint \mathbf{a} \cdot d\mathbf{r} = \int \nabla \times \mathbf{a} \cdot d\mathbf{s}$$

$$\mathbf{a} \times (\mathbf{b} \times \mathbf{c}) = \mathbf{b} \mathbf{a} \cdot \mathbf{c} - \mathbf{c} \mathbf{a} \cdot \mathbf{b}$$

MATRICES

$$\mathbf{y}_1 = a_{11}x_1 + a_{12}x_2 + a_{13}x_3$$

$$\mathbf{y} = \mathbf{A} \mathbf{x}$$

$$\mathbf{y}_2 = a_{21}x_1 + a_{22}x_2 + a_{23}x_3$$

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = [\mathbf{A}_{ij}]$$

$$\mathbf{y}_3 = a_{31}x_1 + a_{32}x_2 + a_{33}x_3$$

$$\mathbf{x} = \mathbf{A}^{-1} \mathbf{y}$$

RATIONAL APPROXIMATIONS

$F(z)$	$R(z)$
$K_0(z), K_1(z)$	$\left(\frac{2z}{\pi}\right)^{\frac{1}{2}} e^z F(z)$
$K_{\frac{1}{2}}(z), K_{\frac{3}{2}}(z)$	$\left(\frac{2z}{\pi}\right)^{\frac{1}{2}} e^z F(z)$
$E(z) = \int_{-\infty}^{\infty} \frac{e^t}{t} dt$	$ze^{-z} F(z)$
$E(z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \frac{e^t}{t} dt$	$\sqrt{2\pi} ze^{-z} F(z)$
$D(z) = \int_{-\infty}^{\infty} \frac{du}{u} \int_{-\infty}^{\infty} \frac{e^t}{t} dt$	$z^2 e^{-z} F(z)$
$D(z) = \int_{-\infty}^{\infty} \frac{du}{u} \int_{-\infty}^{\infty} \frac{e^t}{t} dt$	$z^{\frac{1}{2}} e^{-z} F(z)$
$h(z) = \int_0^{\infty} \frac{e^{-u}}{u} \int_{-\infty}^{\infty} \frac{e^t}{t} dt du$	$z F(z)$
$m(z) = \int_0^{\infty} \frac{e^{-u}}{u} \int_{-\infty}^{\infty} \frac{e^t}{t} dt du$	$\frac{1}{2} z^{\frac{1}{2}} F(z)$

RELATIVITY

That the velocity of light is independent of the motion of the observer was indicated first by the experiments of Michelson and Morley. The constancy of the velocity of light is only one manifestation of the principle of relativity, which may be stated in the following way.

It is not possible by any physical experiment to determine an absolute motion through space.

An implication of the principle of relativity is that all scalars, vectors, and tensors which represent physical quantities are invariant with respect to the speed of the reference frame to which they are referred.

Let a spherical light wave emanate from an origin of coordinates at zero time and expand with the speed of light. The equation of the light wave is

$$x^2 + y^2 + z^2 - c^2 t^2 = 0 \quad (1)$$

where x, y, z, t are the Cartesian coordinates and the time of a point in the light wave and c is the speed of light. Invariance of the scalar function in Equation (1) implies that a position vector r with coordinates

$$(x, y, z, ict) \quad (2)$$

is invariant in a four-dimensional space whose metric is given by the equation

$$(dl)^2 = (dx)^2 + (dy)^2 + (dz)^2 - c^2(dt)^2 \quad (3)$$

The vector r may be differentiated with respect to the metric l to obtain new invariants which satisfy the identity

$$\frac{d}{dl} \left(\frac{dx}{dl} \cdot \frac{dx}{dl} \right) = 2 \frac{dx}{dl} \cdot \frac{d^2x}{dl^2} = 0 \quad (4)$$

Associated with a particle is a rest mass m_0 which is a physical quantity and is invariant by the principle of relativity. Associated with the particle is a momentum vector p which may be defined by the equation

$$p = im_0 c \frac{dr}{dt} \quad (5)$$

Application of the identity (4) to the momentum vector p leads to Einstein's law of the equivalence of mass and energy. The prediction of the equivalence of mass and energy is one theory which has been confirmed in the most spectacular way by practical applications. It gives the source of energy for nuclear bombs.

STARS
POSITIONS AT 1950.0

CATALOG NUMBER	RIGHT ASCENSION	DECLINATION	NAME
MAIN SEQUENCE STAR			
☉	18 ^h 43 ^m 12 ^s	-23° 04' 37"	Sun
Planet			
♁	-	-	Earth
Satellite			
☾	03 ^h 49 ^m 50 ^s	+23° 54' 21"	Moon
DOUBLE STAR			
GC 8833 ADS 5423	06 ^h 42 ^m 57 ^s	-16° 38' 46"	Sirius
Brightest Star			
BS 2491	06 ^h 42 ^m 57 ^s	-16° 38' 45"	Alpha Canis Majoris A
White Dwarf			
-	06 ^h 42 ^m 57 ^s	-16° 38' 49"	Alpha Canis Majoris B
TRIPLE STAR			
GC 19728	14 ^h 36 ^m 11 ^s	-60° 37' 49"	Rigel Kentaurus
Main Sequence Star			
BS 5459	14 ^h 36 ^m 11 ^s	-60° 37' 53"	Alpha Centauri A
Main Sequence Star			
BS 5460	14 ^h 36 ^m 11 ^s	-60° 37' 44"	Alpha Centauri B
Nearest Star			
-	14 ^h 26 ^m 19 ^s	-62° 28' 05"	Proxima Centauri
PULSAR			
NP 0532	05 ^h 31 ^m 31 ^s	+21° 58' 55"	Taurus XR-1
Supernova of 1054AD			
NGC 1952 M 1	05 ^h 31 ^m 31 ^s	+21° 59' 01"	Crab Nebula
GALACTIC CLUSTER			
- M 45	03 ^h 43 ^m 9 ^s	+23° 58'	Pleiades Cluster
GLOBULAR CLUSTER			
NGC 6205 M 13	16 ^h 39 ^m 9 ^s	+36° 33'	Hercules Cluster
SPIRAL GALAXY			
MW	17 ^h 42 ^m 28 ^s	-28° 58' 30"	Milky Way Galaxy
Irregular Galaxy			
SMC	00 ^h 50 ^m 0 ^s	-73° 00'	Small Magellanic Cloud
Irregular Galaxy			
LMC	05 ^h 28 ^m 0 ^s	-68° 00'	Large Magellanic Cloud
SPIRAL GALAXY			
NGC 224 M 31	00 ^h 40 ^m 0 ^s	+41° 00'	Andromeda Galaxy
Elliptical Galaxy			
NGC 205	00 ^h 37 ^m 8 ^s	+41° 25'	-
Elliptical Galaxy			
NGC 221 M 32	00 ^h 40 ^m 0 ^s	+40° 36'	-
QUASAR			
3C 273	12 ^h 26 ^m 33 ^s	+02° 19' 42"	-

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

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